ANIMAL MECHANISM

AND

PHYSIOLOGY;

BEING A PLAIN AND FAMILIAR EXPOSITION OF THE STRUCTURE AND FUNCTIONS OF

THE HUMAN SYSTEM.

DESIGNED FOR THE USE OF FAMILIES AND SCHOOLS.

BY JOHN H. GRISCOM, M.D.,

PROFESSOR OF CHEMISTRY IN THE NEW-YORK COLLEGE OF PHARMACY, AND LECTURER ON ANIMAL MECHANISM AND PHYSIOLOGY.

"For shall the work say of him that made it, He made me not? or shall the thing framed say of him that framed it, He had no understanding?"—ISAIAH xxix., 16.

ILLUSTRATED BY NUMEROUS WOODCUTS BY BUTLER.

NEW-YORK:

HARPER & BROTHERS, 82 CLIFF-STREET.

1840.

PREFACE.

The term *Animal Mechanism*, in the title of this work, is substituted for *Anatomy*, as pointing more particularly to the *mode* in which the structure of the human body is described, and not as indicating any difference in the objects themselves, from those which are usually considered under the latter head. For the purpose of making the study of anatomy more easy and agreeable, the human frame is considered, in the following pages, as a *machine*, composed of apparatus of various kinds, adjusted to each other in a surpassingly ingenious manner, carrying on their apparently incongruous operations without interruption from each other, and all working together for the attainment of the one great end for which the machine was devised with the most perfect harmony.

This view of the subject cannot justly be considered to derogate from the exalted interest which the contemplation of this last and noblest work of the Creator should always inspire. Apart from the fact that the animal structure can be shown to be a combination of implements acting upon well-known philosophical and mechanical principles, bringing to its aid the sciences of Chemistry, Hydraulics, Hydrostatics, Pneumatics, Mechanics,

Optics, and Acoustics, this manner of exhibiting its different departments proves it incontrovertibly to be the work of premeditation, inasmuch as contrivance and design are demonstrable in each part of the machine.

Anatomy, as it is usually taught in schools and in books, is simply a description of the various tissues of the body, taken up one by one, the use of each being pointed out conjointly with its description. To the general student, the subject is thus deprived of much of its interest, and the study itself is rendered more tedious and irksome; while the contemplation of the various organizations in their mutual dependencies, and the perfection of their relations, is in a great degree lost or obscured.

It is, therefore, in connexion with the objects for which they have been created, that the various organs of the human frame are described in this work; in other words, the nature of the function being explained, the apparatus employed to effect it is described, so that its applicability to the purpose is at once seen.

To exhibit in a clear light the ingenuity which has been employed in the construction of this wonderful fabric, comparisons have in some instances been instituted between these works and those of art, and the examination may be safely committed to any one who will undertake it in the spirit of candour and truth.

Occasion is taken, also, to compare the construction of individual organs of the human frame with the corresponding organs of inferior animals; by this means a more just conception may be obtained of the wisdom displayed in the human fab-

ric, adapted, as it must be, to the superior intelligence and more elevated rank of man. Every animal is, indeed, perfectly adapted, by its formation, to the sphere in which it was intended by nature to live and move; and if any apparent defect exists, it is safe to conclude that what we should presume a nearer approach to perfection would, in fact, be an unnecessary refinement, if not a positive inconvenience.

In alluding to those supposed defects of organization in some of the lower animals, with regard, for example, to the sloth, and others of the Tardigrade species, which are remarkable for the sluggishness of their movements, the author of "the Hand," one of the Bridgewater Treatises, makes the following just remarks:

"Modern travellers express their pity for these animals: while other quadrupeds, they say, range in boundless wilds, the sloth hangs suspended by his strong arms; a poor, ill-formed creature, deficient as well as deformed, his hind legs too short, and his hair like withered grass; his looks, motions, and cries conspire to excite pity; and, as if this were not enough, they say that his moaning makes the tiger relent and turn away. This is not a true picture: the sloth cannot walk like quadrupeds, but he stretches out his strong arms, and if he can hook on his claws to the inequalities of the ground, he drags himself along. This is the condition which authorizes such an expression as 'the bungled and faulty composition of the sloth.' But when he reaches the branch or the rough bark of a tree, his progress is rapid; he climbs hand over head along the branches till they

touch, and thus from bough to bough, and from tree to tree; he is most alive in the storm; and when the wind blows, and the trees stoop, and the branches wave and meet, he is then upon the march."

Anatomy is that science which teaches us the *structure* of animal bodies.

Physiology unfolds to us the *nature* of the different parts, and of the functions which they perform.

The latter science consequently depends much for its elucidation upon its sister science chemistry.

The chemist knows that it is by the combination, in different proportions and quantities, of a comparatively few simple elements, that the great number of natural bodies is formed; so, likewise, the anatomist can show that the various structures of animal bodies are composed of a few original elementary tissues.

The number of these tissues, whose varied combinations form all the organs of animal bodies, has been reduced to the following short list:

1. Cellular.
2. Adipose or medullary.
3. Vascular.
4. Nervous.
5. Osseous.
6. Fibrous.
7. Cartilaginous.
8. Fibro-Cartilaginous.
9. Muscular.
10. Spongy.
11. Mucous.

12. Serous.
13. Dermoid, or Skin.
14. Glandular, as Liver, Kidneys, &c.

Some of the organs consist of only one of these tissues, while others are compounded of two or more of them in various proportions. We speak now of the solid parts of the animal structure, the fluids, which constitute a large part of the bulk of the body, not being enumerated in the foregoing list. Those fluids which are concerned wholly or in part in the formation of the body, are,

1. The Blood.
2. The Gastric Juice.
3. The Saliva.
4. The Bile.
5. The Pancreatic Juice.
6. The Optic Humours.

Besides these, we find a few which, though more abundant in quantity than some of the preceding, must be ranked as excretions, and not looked upon as essential to the system ; these are,

1. The Perspiration.
2. The Urine.
3. The Tears.

As far as modern researches in chemistry have extended, the fact has been developed that there are but fifty-four elementary substances, by whose varied combinations all the materials of the universe are composed.

The immense varieties of matter known to us are chemically distinguished from each other chiefly by their composition.

In the inorganic world we find all the elements or simple substances of the chemist; but in or-

ganic nature the case is very different. All vegetable and animal bodies are composed in general of a few elements, and differ in chemical composition but by slight variations in the number, proportions, and juxtaposition of their combining elements.

The simple substances which are found to constitute the great bulk of animal matter, are *Oxygen*, *Hydrogen*, *Carbon*, and *Nitrogen*. A few of the other elements are found to give a character to some specific substances. Thus the bones contain phosphorus and lime, the blood iron, &c. So, also, some animals contain some substances in some part of their structure, by which they are distinguished from all other creatures.

The *functions* which are considered in this volume are those of,

1st, Circulation.
2d, Respiration.
3d, Speech.
4th, Secretion.
5th, Muscular Action.
6th, Nervous Action.
7th, Digestion; and,
8th, Those of the Osseous System, the latter being alluded to only as its different parts relate to, and are connected with, the other functions. The study of the bones, although presenting as many points of interest as any other, has generally been considered as *dry* as the subjects themselves, even to those who are especially interested in the acquisition of anatomical knowledge. It could not be expected, therefore, under the old mode of treating the subject, even in popular works, that the general student would find the study sufficiently in-

teresting to enable him to peruse it without tedium or perhaps dislike.

To divest this interesting branch of knowledge of its repulsiveness, and to render it more easy and attractive, has been the object of every attempt at popular physiology. And a wish to contribute something that may render the knowledge of the structure of our frames more general among non-professional people, is the author's inducement for submitting this little work to the public. How far it may prove to be a valuable addition to those already known, can be determined only by time and experience. One prominent motive, he is free to confess, has been the desire to render the study of our frames subservient to moral improvement, by furnishing the young reader with incontestible evidence of a Great First Cause. This, he is aware, is treading in a path over which many brilliant minds have gone before, and it may seem presumption in him even to follow them.

With all proper deference, however, to their valued productions, it is his impression that no work has yet come to his knowledge which exclusively, and with sufficient amplitude and freedom from technicalities, treats of the mechanism of the human body, either with or without reference to this great point, with that simplicity which is needful for general readers and common schools.

The arrangement of the subjects treated of in this work, he apprehends, is new; but the peculiar mode of teaching them is, with some variations, that which has been so successful in the hands of Sir Charles Bell, Dr. Arnott, and a few other modern writers. The plan has been more fully car-

ried out than in any single work that the author has met with, and he hopes that this little book may be productive of some (if not as much) of the good fruits which have followed the plantings of others in this field of popular knowledge.

Without the aid of that book which leads to a still closer acquaintance with the author and finisher of this magnificent universe, these studies are a sufficient proof of the existence of an Omnipotent Designer; for that wisdom must be almighty that could adapt such apparently incongruous ends to each other, and blend into one harmonious whole the millions of different ranks in the great scale. Nor only this; it proves that *one* mind alone has conceived, and *one* hand executed and perfected, the great and incomprehensible work of the universe; the singleness of an individual power could alone produce it; no division of mind could have accomplished it. We are therefore impelled to the conclusion, that the Power which created the heavens; "which maketh Arcturus, Orion, and Pleiades, and the chambers of the South;" the earth, and all that is therein; even man, the most perfect and complex of all created beings, is one in all his manifestations.

CONTENTS.

CHAPTER I.

CIRCULATING APPARATUS.

CHAPTER II.

RESPIRATORY APPARATUS.

CHAPTER III.

VOCAL APPARATUS.

CHAPTER IV.

THE BLOOD

CHAPTER V.

MOTORY APPARATUS.—Part 1st.

CHAPTER VI.

MOTORY APPARATUS.—Part 2d.

CHAPTER VII.

PHYSIOLOGY AND EFFECTS OF EXERCISE.

CHAPTER VIII.

THE HAND.

CHAPTER IX.

THE SKIN.

CHAPTER X.

THE NERVOUS SYSTEM.

CHAPTER XI.

PROTECTION AFFORDED TO THE BRAIN AND SPINAL MARROW.

CHAPTER XII.

THE "PACKING" OF THE BODY.

CHAPTER XIII.

DIGESTIVE APPARATUS.

CHAPTER XIV.

THE SENSES.

Several selections will be found in this work from the pages of other authors, but it has not been deemed necessary to specify at each quotation the book from which it is taken; a general acknowledgment, it is presumed, will be sufficient. It is believed that no quotation has been given without its being indicated by the usual typographical marks.

The following list comprises the works from which extracts have been made: numerous others have been consulted.

Arnott's Elements of Physics.—Beaumont's Experiments on Digestion.—Bell on "The Hand."—Bell and Brougham's Illustrations of Paley.—Bostock's Physiology.—Combe's Physiology.—Dunglison's Physiology.—Family Magazine.—Horner's Anatomy.—Library of Useful Knowledge.—Medico-Chirurgical Review.

ANIMAL MECHANISM

AND

PHYSIOLOGY.

CHAPTER I.

CIRCULATING APPARATUS.

1. There are to be found in many large cities, as New-York, Philadelphia, and London, arrangements for supplying them plentifully with water, to be used by the inhabitants for the various purposes of drinking, bathing, extinguishing fires, cleansing the streets and houses, &c. This supply is furnished by means of an extensive apparatus, composed of, 1st, A basin elevated above the tops of the houses, as on a hill, or on a place built purposely for it, into which basin the water is forced by a waterwheel or a steam-engine; 2d, Of a large pipe running from the bottom of this basin towards the city, under ground; and, 3d, Of an arrangement of smaller pipes leading from the large one, which, by dividing and subdividing, serve to convey the water, not only into every street, but into every lane, every alley, every house, and every room in the house, where, by turning a stopper, any person can obtain a full supply of this necessary fluid.

One of the most simple and economical arrangements for this important purpose is to be found in Philadelphia. The water of the Schuylkill River, which is there used, is, by an ingenious yet very simple contrivance of waterwheels and forcing-pumps, *made to raise itself* to the basin on the top of a high mound, whence it circulates through many miles of pipe, and unnumbered ramifications, into every corner of that large city. Not the least beautiful part of this arrangement is, that the stream, as it flows along, keeps in motion the apparatus which raises the water of the same river to the basin. So that, supposing the machinery to be always in order, as long as the river continues to run, so long will the city be copiously supplied with the healthful fluid, requiring only the care of one man to regulate the quantity in the reservoir.

2. Besides this apparatus of pipes just described, the houses and streets of the cities are farther supplied with an arrangement of channels and sluices for the purpose of conveying away the water which has been used, called "waste water." To this end we find each house furnished with a "waste pipe," which empties into a channel in the alley of the house; this channel empties into the gutter of the street; several of these unite to form larger gutters, and the latter continue on to a "sewer" under ground, which collects the water from all the large gutters on the surface, and conveys it to the river whence it came, but emptying into it at a point at a distance below the waterworks, that the pure water may not be contaminated.

3. The impure water, after being thrown back into the river, is, by the heat of the sun and other

causes, evaporated, the impurities being left behind; and the vapour, being lighter than the air, rises high above the earth, and is there condensed, forming clouds, which after a while empty themselves upon the earth in the form of rain, which runs into the river. The water is thus purified and rendered fit for use again. So, if we could suppose the Schuylkill the only river anywhere near Philadelphia, and the supply from the clouds sufficient for the purpose, the inhabitants of that city would use the same water over and over again an indefinite number of times.

4. There is in the human body a circulating apparatus very analogous to this in many particulars. It is for the purpose of carrying through the system a peculiar and very important fluid, the Blood; the circulation of which is the principal means whereby the body is made to grow in size and strength, and by which fresh material is deposited in the place of the old, which has worn out or otherwise become unfit for use.

5. Like the apparatus which supplies a city with good water, that which supplies the animal body with blood is composed of several distinct parts.

There is, first, a powerful and complicated machine, which receives the blood into its cavities, and then acting upon it like a forcing-pump, propels it into the

Second part of the apparatus, which consists of a very extensive series of tubes or pipes, through which the blood is conveyed to all parts of the body, to give it nourishment and health, and to take up the decayed and unhealthy particles.

The third part consists of another set of pipes,

which collects all the blood after it has been used and has become impure, in order to return it to a part of the body where it may be renewed, and made fit to nourish the body again.

In the last place, the impure blood undergoes the process of purification, by which it is completely restored to its healthy state, being deprived of all its noxious properties, and, like the water from the clouds, is again good for use. It is then put back into the first machine, and again sent through the proper pipes all over the system.

6. The machine which, in the animal body, is used to force the blood into the pipes, is the *Heart*.

The first set of tubes, which receive the blood immediately from the heart, are called *Arteries*. These carry the fluid through the whole system, and it passes from them, after being used, into the next set of vessels, called *Veins*, which carry it back.

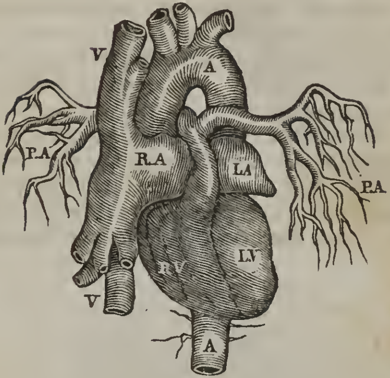
The organs in which the blood is purified are called *Lungs*, and from them it is returned to the heart, to be recirculated through the same channels.

7. The following are, then, the organs concerned in the transmission and purification of the blood, viz., the heart, arteries, veins, and lungs. All of these organs, but especially the first, are very beautiful and complicated in their structure, and are worthy a minute acquaintance.

OF THE HEART.

8. The heart is situated in the chest, behind the breast-bone, and its motion may be felt by the hand when placed on the left breast. It is of about the size, in the adult, of a man's fist, and is com-

Fig. 1.



The Heart, as it appears when isolated from all surrounding parts.

posed almost entirely of strong muscular fibres. Its shape is conical, and it is situated with the apex pointing downward and to the left side, while the base is above and towards the right side.

9. All animals which breathe atmospheric air have hearts divided inside into *four chambers*, separated from each other by strong muscular walls. In those animals which do not breathe, as fishes, the heart has only two cavities. Breathing animals have, therefore, *double hearts*, and non-breathing animals have *single hearts*.

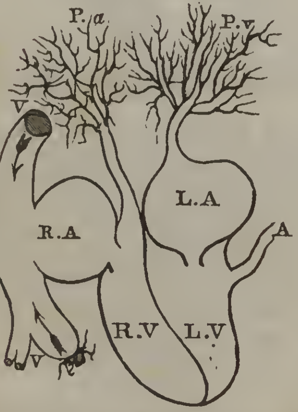
In breathing animals one half the heart is for the purpose of propelling the blood into the lungs, there to be purified; and the other half is for sending the blood through the arteries into the

body. When it returns through the veins, therefore, it empties into one part of the heart, and thence is sent to the lungs.

Non-breathing animals having no lungs, a single heart only is required. Their blood is purified in another manner.

10. Double hearts are divided anatomically into *two sides*, the right and left, each having two cavities. The right side receives the blood from the veins, and sends it into the lungs; the left side receives it from the lungs, and sends it through the body.

Fig. 2.



These cavities are called auricles* and ventri-

* Derived from auricula (Latin), an ear; from its resemblance in shape to a dog's ear.

cles.* In the right side there is one auricle and one ventricle, and one of each also in the left side.

This *diagram* (fig. 2) shows the relative situation of these four cavities. The blood enters the heart from the great veins V. V. These throw it into the right auricle R. A. Thence it goes into the right ventricle R. V.; and from that cavity into the lungs, through a bloodvessel called pulmonary artery, P. a. After being purified, it returns to the heart through another bloodvessel, the pulmonary vein, P. v., which empties into the left auricle L. A., and that empties itself into the left ventricle L. V. From this last cavity it is sent to the body through the main pipe A., called *Aorta*, which is the largest artery in the system.

11. When the right auricle has become filled with the blood from the veins, its sides, which are formed of strong muscular fibres, contract upon it, and thus reduce the dimensions of the cavity, by which means the blood is forced into the adjacent ventricle. The ventricle consequently becomes distended; and when it is filled, its walls, which are stronger than those of the auricle, on account of its having to send the blood farther, also contract, and force the blood through the pulmonary artery into the lungs.

When the blood returns from the lungs to the left side of the heart, the contractions and dilatations there correspond exactly with those of the right side.

The auricles expand together, and contract also at the same moment.

* From ventriculus (Latin), a stomach; from its fancied resemblance to a stomach in form.

The ventricles are likewise simultaneous in their movements.

12. Each auricle and each ventricle has, of course, two openings, one for the entrance and the other for the exit of the blood. By reference to the preceding diagram, it will be seen that the two openings in each ventricle are equally in the direction of the current, when the ventricle contracts upon the blood to expel it. Were it not for a wise and most beautiful provision, the blood would be as likely to return to the auricle as to go out the proper way.

A pair of common bellows will illustrate this. It has two openings, one through the nozzle, and the other, much larger, in one of the boards. When the boards are pulled apart, the air enters through the latter hole; and when they are forced together, the air would pass as rapidly out through the same opening as it entered, were it not prevented. This is done by a leather flap or valve, which covers the opening inside, and the air is consequently all forced out through the nozzle, the place designed.

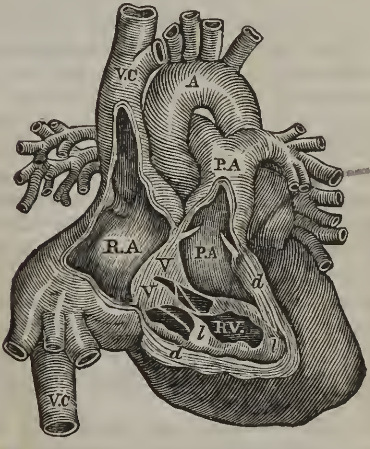
The action of each ventricle is precisely analogous to that of the bellows, the blood being prevented from going back into the auricle by an arrangement of delicate little valves represented in the annexed cut (fig. 3).

13. These valves are three in number in the right, and two in the left ventricle, and are made of exceedingly fine membrane, of a peculiar texture, so thin as to be translucent, yet strong enough to sustain the whole power of the ventricle. Their shape is somewhat triangular, and similar to that

of the moon when gibbous, or about three quarters full. The opening between the two cavities is nearly circular, and about one inch in diameter. The valves are attached by one edge to the inside of the opening very firmly, while the other edge is loose, and floats backward and forward as the blood moves it.

14. When the right auricle contracts, the blood is pushed against the valves, which give way and allow it to pass; but when the ventricle contracts,

Fig. 3.



Right side of the heart, laid open to show the valves. V. C., V. C., the great veins bringing the blood to the heart. R. A., the right auricle. R. V., the right ventricle. Between the two are seen the valves V. V., and to them are attached the tendinous cords which are fastened by muscular fibres *l. l.* to the inside of the ventricle.

the blood is forced against the opposite sides of the valves, and pushes them to, like little doors. They fall against each other, and completely close the opening so as entirely to prevent the blood from going back into the auricle.

15. But the valves could not, unaided, withstand the current against them, and would themselves be forced into the auricle, were it not for a guard with which they are most effectually furnished.

16. This consists of a number of extremely small, delicate, silk-like cords, made of fine tendon, which are fastened by one end to the loose edges of the valves, and by the other end to the wall of the ventricle inside, and directly opposite the opening from the auricle (figure 3). These fine cords run, therefore, immediately across the cavity of the ventricle; they are very flexible and strong, and are just long enough, when the ventricle is distended, to allow the valves to lie flat and cover the opening completely; and short enough to prevent them being pushed through into the auricle. They act very much like the ropes attached to the corners of the jib sails of a ship, which keep the sails from being blown away by the wind. The ropes have no contractility, and hold the sail merely by their strength; the cords of the valves are equally devoid of contractility, and, though very fine, are possessed of great strength.

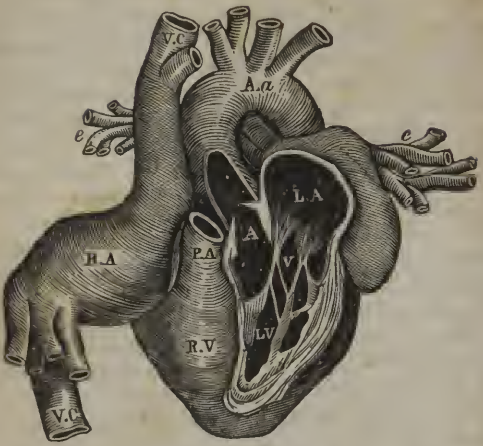
17. But this is not all the beauty and ingenuity of this wonderful and delicate mechanism. These tendinous cords are of exactly the requisite length, when the ventricle is fully expanded, to keep the valves in their proper places. But when the ventricle contracts, and its sides are

brought nearer to each other, it is apparent that the cords must become loosened, and the valves be allowed to float into the auricle, and thus destroy their use as valves, without some preventive against such an accident. Such a preventive is beautifully provided. The cords are attached to the ventricle by the intervention of little muscles (*l. l.*, fig. 3), which contract at the moment the ventricle contracts, in an opposite direction, and just enough to keep the cords always at the same degree of tension. When the ventricle expands, these muscles relax in a corresponding degree, so as to elongate the cords and accommodate them to the varying diameter of the ventricle.

The action of the valvular apparatus in the left side of the heart corresponds precisely with that of the right side, except that there are but two valves in the former instead of three, as in the latter (fig. 4).

18. There is still another kind of valvular action in the operations of this curious and interesting organ, much simpler, but equally efficacious with the last, which is very similar in principle to that found in the common pump. In the tube of this useful instrument there is a fixed block, with a hole through it, fastened to which is a valve of leather, which opens upward and allows the water to ascend freely through it. But the instant the water begins to descend, the valve falls down over the hole in the block, stopping it up completely, where it is kept by the weight of the water above, and prevents its descent. Another valve, precisely similar to this in its make and action, is attached

Fig. 4.



Left side of the heart, with the valves. R. A. and R. V., the right auricle and ventricle. P. A., the pulmonary artery, cut off near its origin, to show the aorta, A. *a*. L. V., the left ventricle. L. A., the left auricle. V. is between the valves which command the opening between the auricle and ventricle. A. is the mouth of the aorta, with its valves hereafter described. *e. e.*, branches of the pulmonary artery.

to a block which moves up and down in the pump with the piston-rod.

19. In each of the two great arteries which carry blood from the heart (one from the right ventricle to the lungs, the other from the left ventricle to the body), is found an admirable arrangement of valves acting on principles precisely similar. A description of one will suffice for both.

The aorta, or main artery of the body (A. a.,

fig. 4), is about one inch in diameter, and as it rises from the left ventricle, ascends perpendicularly about three inches before it makes a curve to descend. When the ventricle contracts, the blood is forced into the aorta, which becomes filled; and the moment the ventricle begins to expand, the blood in the aorta begins to fall, and would inevitably return into the cavity, were its progress not arrested by a set of valves placed at the mouth of the artery (A., fig. 4).

Fig. 5.

V., the upper part of the ventricle, and A., the aorta, rising from it. At the mouth of the artery are seen profiles of two of the valves, open to admit the blood from the ventricle. At this point the diameter of the arterv is a little larger, to serve the purpose mentioned in the text.

20. "At the root or origin of the aorta, there is a firm ring, to which the valves now to be described are attached. The necessity of this will appear evident, since, if the ring could be stretched by the force of the heart's action, the valves or floodgates would not be sufficient to close the pas-

sage; their conjoined diameters would not equal that of the artery which they have to close. These valves are three in number; they are little half-moon shaped bags of thin membrane, which are thrown up by the blood passing out from the ventricle, but by the slightest retrograde movement of the blood their margins are caught, and then, being distended or bagged, they fall together and close the passage.

Fig. 6.

Represents the figure which the three semilunar valves placed at the mouth of the aorta assume when distended by the refluent blood.

"There are some curious little adjuncts to these valves, which ought to be explained, as showing the accuracy of the mechanical provision.

"When the margin of the valve is thrown up by the blood passing out of the heart, it is not permitted to touch or fall flat upon the side of the artery, for if it did it would not be readily caught up by the blood that flows back; there is, therefore, a little dilatation of the coats of the artery, forming a pouch behind each valve, by which, being always full of blood, although the margins of the valve be distended to the full circle, they never cling to the coats. These valves, then, are never permitted to fall against the coats of the artery, and, therefore, they are always prepared to receive the motion of the refluent blood.

"To strengthen the valves, a tendon runs along their margin like the bolt-rope or foot-rope along the edge of a sail, and these tendons are attached to the side of the artery, and give the valve great strength." They effectually secure the valves against being torn at their edges.

21. All the beautiful and intricate apparatus which is here described, and much more not particularly described, it must be recollected, is contained in an organ not larger than a large man's fist; every part of it is, moreover, kept incessantly in motion, from the first dawning of life until the last breath of the individual. If this should produce surprise in any one, how much must that be increased when he is told that the contractions and expansions of the heart, and, of course, the opening and shutting of these little valves, take place, on an average, about seventy times in a minute; and sometimes, in a state of disease, as often as 150 times a minute.

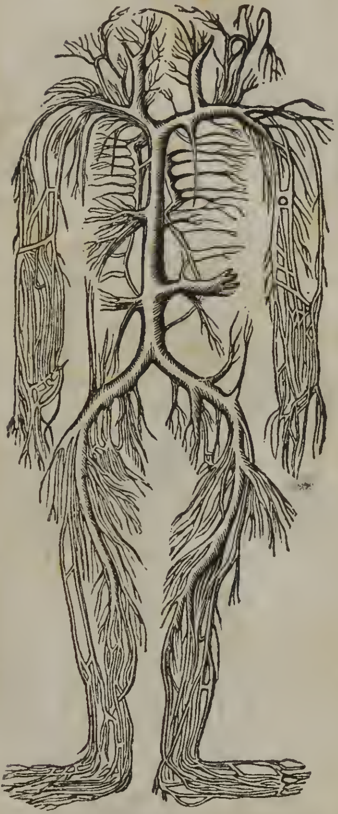
22. The heart belongs to that class of muscles

termed involuntary, i. e., not under the control of the will. It is entirely out of our power to cause the heart to stop acting except by mechanical violence. The existence of our lives depends immediately upon the action of this organ, for we die the moment it ceases to beat. It is the first to move and the last to die. Seeing its vast importance, is it not a subject for our profound admiration that its operations should be placed entirely beyond the reach of our will? a will proverbially fickle, uncertain, and treacherous. Had it been made a part of our duty to attend to the regulation and continuance of the minute and complicated actions of this important organ, we should never be able to give our attention for an instant to any other subject; and "a doubt, a moment's pause of irresolution, a forgetfulness of a single action at its appointed time, would terminate our existence."

OF THE BLOODVESSELS.

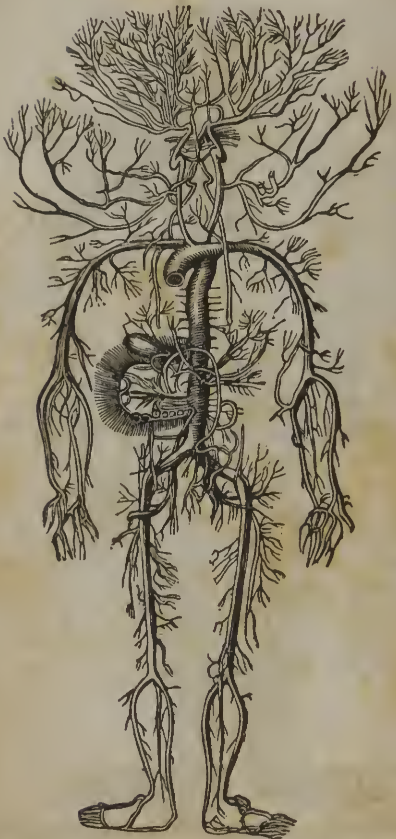
23. Having described the organ which propels the blood into the circulating pipes, these must next be explained. They consist, as already stated (6), of two sets, viz., the *Arteries*, which carry the blood through the system, and the *Veins*, which bring it back to the heart. The annexed plates will present a very good general view of both these systems of bloodvessels.

Fig. 7.



Venous System, or principal veins of the body; the large vein in the centre being the vena cava, into which all the minor veins empty themselves.

Fig. 8.



ARTERIAL SYSTEM, or principal arteries of the body; the main artery in the centre being the AORTA, communicating with the heart, where it appears cut off.

24. In comparing these bloodvessels with the water-pipes of a city, several striking differences are to be noticed.

1st, The *water-pipes* are rigid, firm, inflexible, inelastic tubes. 2d, They cannot be bent without breaking. 3d, They cannot grow larger or smaller, nor alter their position in any way. 4th, They have no power in themselves to propel their contents onward, but the water runs through them entirely without aid from them. On the contrary, the *bloodvessels* are, 1st, Soft, very flexible, and very elastic, yet strong. 2d, They can be bent to any extent without danger, as is exemplified in those which run over the joints, and wherever any motion is made in the body. They adapt themselves readily to any position. 3d, They change in size as the growth of the body requires, and as they have more or less blood to convey. 4th, They have a power in themselves by which they assist in propelling their contents forward.

25. There is considerable difference between the structure of the arteries and that of the veins. The former are denser, much thicker and firmer, and much more elastic than the veins, and afford great assistance to the heart in forwarding the blood. The veins are thin, soft, and have little or no elasticity. Many of the veins being very long, and having a high column of blood to hold, as in the leg from the foot to the hip, they are furnished at intervals with little valves, which prevent the blood from flowing back, but allow it to pass upward freely; thus any undue pressure on the delicate vessels is avoided.

The only valves in the arterial system are those

already described as at the origin of the aorta and plumonary artery (20).

26. The aorta receives all the purified blood from the heart, and from the aorta arise branches, which run in every direction to supply the various sections of the body. In the little pouch behind the aortic valves are the openings of two small vessels, which supply the substance of the heart with fresh blood. The origin of one of these may be seen in fig. 6. Just at the great curve of this vessel, it gives off two large branches, one to go to each arm; and two more to supply the head, one going up on each side of the neck. It then descends along the left side of the spine, and as it goes past each rib, it gives a branch to each; when opposite the stomach it sends a branch to that organ; so also the liver, the spleen, the bowels, kidneys, bladder, and all the other organs in this part of the body, receive their blood from this vessel.

When it has descended as far as the lower end of the spine, the aorta terminates by dividing into two branches, called iliacs, one of which goes towards each thigh, which, with the leg and foot, it furnishes with blood.

The general direction of the arterial circulation may be pretty well understood by referring to figure 8. It will be seen there that the arteries of the *limbs* are composed of one main branch for each, until they arrive at the elbow and knee joints, when they divide into two branches, one running down each bone.

The minute ramifications at the top of the figure give a slight outline of the circulation of the head and brain.

28. The venous circulation, with a few differences, follows nearly the same route as the arterial. There are about the same number of main branches, but the smaller ramifications appear to be more numerous, as seen in the figure. The direction of the current of blood, of course, is the reverse of that in the arteries, being from the extremities towards the heart.

Through the veins the blood runs in a very different manner from what it does through the arteries. The former carry it in a regular, uninterrupted current; but through the latter it goes along in jets. By placing the finger on the artery at the wrist or on the temple, its action may be felt; the blood goes along in "pulsations," as they are called, which are simultaneous with the pulsations of the heart; but in the veins there are no pulsations. When an artery is cut so that the blood can run out of it, it goes out in leaps, jutting at every pulsation several feet, if the vessel is not very small. But when a vein is opened, as in bleeding, the blood runs out in a smooth, even stream.

29. It is more difficult to arrest the bleeding from an artery than from a vein, because the arteries are thicker and stouter, and also because they propel the blood with more force. A wound of an artery is, therefore, more dangerous than a wound of a vein.

On this account chiefly we find the two systems placed in different situations in the body and limbs. The larger *arteries* are placed as far as possible from the surface; they run along close to the bones, which give them protection, and they are

freely covered by thick beds of muscle and tendon. On the other hand, an injury of a vein being less dangerous, they are more exposed. They run along near the surface of the body as well as deep under the skin, and in many places they can be distinctly seen, as on the back of the hand and along the arm. If a string or riband is tied moderately tight around the arm above the elbow, the passage of the blood through the veins will be stopped at that point, and below that they will become distended with the blood which runs into them. When a physician wishes to bleed a person, he ties a ligature around the arm just tight enough to arrest the circulation through the veins, and when they have become distended, he opens one with the lancet, and the blood flows out. He has to be careful not to bind it so tight as to stop the circulation through the arteries of the limb, otherwise he will be unable to draw any blood.

OF THE CAPILLARY SYSTEM.

30. Between the arteries and veins there is another system of bloodvessels not yet mentioned. It is called the *Capillary System*, and derives its name from the minuteness of the vessels, they being as fine and finer than hairs.* These vessels, throughout the whole body, occupy a place, and are the connecting link, between the extremities of the arteries and the commencement of the veins, and transmit the blood from one to the other. Their functions are not less important than those of any other part of the circulating apparatus. It

* From the Latin word *capillus*, a hair.

is a part of their duty to receive from the arteries the pure and healthy blood, to take from it the new material and deposite it in its proper place, and at the same time to take up the worn-out and impure matter of the body and carry it to the veins, to be removed by them from the system.

31. "From the capillaries the peculiar fluids are secreted, the body is nourished, and many other processes are accomplished. Their number is considerably greater where secretion is to be performed, than where their object is only the nutrition of the part. For this reason, the liver, stomach, &c., which secrete certain fluids that are essentially necessary to the system, are supplied with a greater quantity than the bones, ligaments, and skin; and, indeed, so extensive is their distribution, that these important organs seem to be almost wholly made up of an immense network of capillary vessels."

32. These being the objects of this set of vessels, it will at once be perceived that they must occupy every point of the entire body. Every particle of the body, in process of time, becomes by age and use unfit to be longer employed, and must be removed, and its place supplied by fresh particles. The removal and deposite are effected by the capillary vessels alone.

33. Moreover, we know that, from infancy to manhood, the body is daily increasing in size; the bones grow longer and stouter, the muscles grow larger and stronger, and the whole frame becomes in a few years a hundred or more pounds heavier. This is brought about in the following manner: the nutritious portion of our food is converted into blood; the heart and arteries carry the blood all

over the body; the capillaries select the proper particles for each organ from the blood, and deposite it in its right place. We may thus see something of the importance of these little agents; and the *universality* of their existence in the body may be learned from the fact, that the point of the finest needle cannot be thrust into any sensible part of the body without its withdrawal being followed by a drop of blood. This is the case not only in the external skin, but, could we try it, it would be observed also throughout the whole mass of the body, even in the bloodvessels themselves.*

34. Some of these capillaries are so very fine as to be unable, in a healthy state, to carry anything but the thin, colourless portion of the blood. Examples of such are to be found in the tendons, ligaments, nerves, and other parts which are white. The white parts of the eyes are striking instances. In these and other parts, even where they do convey red blood, they are so fine that a powerful microscope can scarcely detect them. But when they are excited by disease to increased activity, they become enlarged by too much blood being forced into them, and those which should be white become red, and "inflammation" is the result. This may be seen in an inflamed or bloodshot eye, or in inflammation of the skin, when the white capillaries are filled with red blood; and it is precisely the same condition of the capillaries which

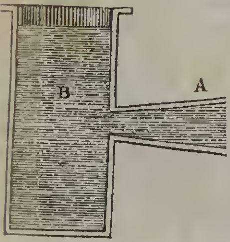
* To prove that the *Bones* are supplied with capillary bloodvessels, Professor Mussey fed a pig on food mixed with madder, a vegetable which contains a great deal of red colouring matter. When the animal was killed, the bones were found throughout of a deep red colour, which could only have been conveyed to them by the circulating apparatus. One of the bones of that pig is in my cabinet, presented by Professor M.

constitutes inflammation of the lungs, stomach, brain, or any other internal part.

THE CAUSES OF THE BLOOD'S PROGRESSION.

35. It is believed now by physiologists, that the power of the heart alone is not sufficient to propel the blood through the whole length of the arteries, but that this organ is aided by the vessels themselves. Some suppose the arteries have a muscular power, and others that their elasticity only is applied to assist in forwarding the blood. Be that as it may, we will now merely advert to the mechanical arrangement of the arteries and their branches, to show how well that is designed to help the blood along. We know when a fluid flows through a pipe of the same calibre throughout, that it meets with much resistance from the friction against the sides of the pipe. But if the pipe should increase in size gradually, from the end where the fluid enters to the other end, not only would the friction of the stream against the pipe be greatly diminished, and the fluid run along more easily, but a *greater quantity* could be sent through it.

Fig. 9.



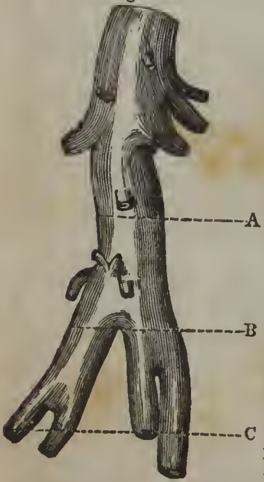
36. Figure nine will exemplify this fact. Let B represent a reservoir of water, and A a conical pipe discharging the water. A pipe of that shape will discharge more fluid than one of the same length whose diameter is the same throughout as at its com-

mencement, "because the gradual expansion of the tube permits the stream from behind to force itself between the filaments,* and disperses them without producing that pressure on the sides of the tube which must take place where it is of uniform calibre."

37. Such is, in effect, precisely the arrangement of the arterial tubes, as explained in fig. 6.

"The celebrated John Hunter took great pains to prove that the artery had its diameter enlarged as it proceeded from the heart, and that the areas of the branches of an artery were greater than the diameter of the parent trunk.

Fig. 10.



That is to say, the section of the trunk at A is not so great as the two sections at B taken together; that the two sections at B taken together are not so great as the four sections at C; that the conjoined diameters, therefore, of the branches of an artery, are greater than the diameters of the artery itself. This fact has been sometimes expressed by saying that the artery was a cone, with its apex in the heart."

It will be seen, therefore, that although the current of blood is gradually

* "Those who treat of hydraulics divide a column of water into ideal lesser columns, which they call filaments."

divided into a great number of smaller streams, it has more and more room as it advances, and, consequently, meets with less impediment to its progress.

38. The manner in which the blood gets through the veins is different from this. These vessels have no power in themselves to push the blood along. They have no elasticity or contractility. To compensate in a great measure for the absence of those properties, they are placed in close contact with the muscles of the body, by whose contractions the veins are almost continually compressed at intervals, and as the valves prevent a reflux of the blood, it is thus forced towards the heart.

This force, conjoined with that of the arteries behind, is the principal means of propelling the blood through the veins.

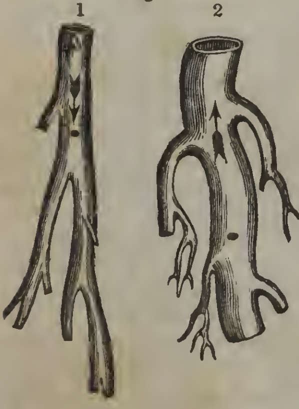
39. There is yet a hydraulic principle discoverable in the construction of the veins which deserves attention, and which, as in the case of the arterial circulation, may be explained by reference to its operation in inanimate tubes. It is shown in the mode or direction in which the smaller veins are connected with the larger, and in the manner in which they are assisted, by that direction, in discharging their contents towards the heart.

To understand more clearly the value of this arrangement, we must observe the modes of distribution of the two classes of bloodvessels, and we shall see a striking difference between them in this respect. In the arteries the fluid flows from the trunk to the branch, and in a reverse direction in the veins; and when we see a decided difference in

the manner in which the trunks and branches of each are united, the mind is at once led to conclude, that, as every fibre of the body is arranged in accordance with a previous design, there must have been a particular object in view in thus arranging the bloodvessels, and we are urged to ascertain the cause or reason for this variation. Sir Charles Bell very ingeniously shows what the design in this case is.

40. The difference is this ; in the arteries the branch leaves the trunk with a slight divergence from the direction of the stream, while in the vein, in which the current is in an opposite direction, the branch joins the trunk at nearly a right angle.

Fig. 11.

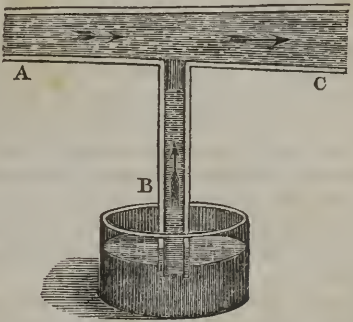


Number one in fig. 11 represents a section of an arterial trunk, with its branches ; and number two the same of a venous trunk.

41. Let us now see whether these various distributions accord with the hydraulic principles established in relation to currents through artificial pipes. "If a pipe be fixed into another contrary to the direction of the stream, the discharge into that lateral branch from the larger tube will not only be much smaller than we might estimate by the

diameter of the tubes, it should be, but in certain circumstances it will discharge nothing at all ; nay, the water will be drawn from the lesser tube into the greater.

Fig. 12.



" Bernouilli found that when a small tube B was inserted into the side of a horizontal conical tube A, in which the water was flowing towards the wider end C, not only did no water escape through the smaller tube, but water in a vessel at a considerable distance below was drawn through the lesser tube into the greater."

Now by figure 10 we have seen that an artery and its branches discharge their contents on the principle of a conical tube, like A C, fig. 12 ; and the reader will at once perceive, that if an arterial branch were inserted into a trunk at or near a right angle, the fluid would not run from the latter into the former, but would be more likely to be drawn *from* the lateral branch.

42. But this is precisely what is wanted in the venous circulation. The vein itself, being of inelastic material, has no power of its own, as has the artery, to assist the flow of the blood, and the arrangement of its branches just described compensates in a degree for that deficiency of its integral structure.

To render the wisdom of this arrangement more striking, let us suppose the reverse to have been the condition of the circulating vessels, viz., the arteries having their branches distributed as are those of the veins, and vice versa. The flow of blood through the arteries would then have been opposed by the hydraulic principle, as explained by fig. 12, and that through the veins deprived of the assistance now afforded it by the present arrangement.

The result must necessarily have been a great retardation of the circulation through both systems of vessels. While the diminished impetus of the blood in the arteries would have deprived the system of much of its present energy and power, the arrestation of it in the veins would have been a continual cause of congestions and inflammations.

43. Another beautiful illustration of the utility of this mode of distribution of the veins, and of the powerful aid it renders in advancing fluids, is given in the chapter on the digestive apparatus, in the description of the manner in which the contents of the thoracic duct find their way into the general circulation.

CHAPTER II.

RESPIRATORY APPARATUS.

44. HAVING, in the foregoing pages, made the comparison between the circulation of water through a city and the circulation of blood through the body, to complete the analogy there is now to be described the manner in which the blood is purified.

When this fluid leaves the left side of the heart to go to nourish the system, its colour is a fresh, bright vermilion; but when it has reached the venous system its appearance is totally changed; it is then a very dark purple, and almost black in colour. This difference constitutes the grand apparent distinction between *arterial* and *venous* blood. The former is alone fit for nutrition, because it is pure and healthy, while the latter is loaded with impurities, and totally unfit to afford nourishment to the body.

45. When a bloodvessel is accidentally opened in the body, there are, therefore, two means of knowing whether it is an artery or a vein. From an artery, the blood will jet out in successive leaps, corresponding to the pulsations of the heart, and it will be of a bright red colour; while the blood from a vein will ooze or run out in a slow, steady stream, and will be of a black colour.

This change in the colour and properties of the

blood is produced in its passage through the capillary vessels. While in them the red blood yields up its healthy, nutritious particles, which are deposited in the various textures of the body, and the decayed portions of the various tissues are taken up and carried into the veins, to be taken to a place where they can be thrown out of the system; or, in other words, where the black blood may be *purified*, revitalized, and restored to its life-sustaining condition by receiving fresh, healthy properties.

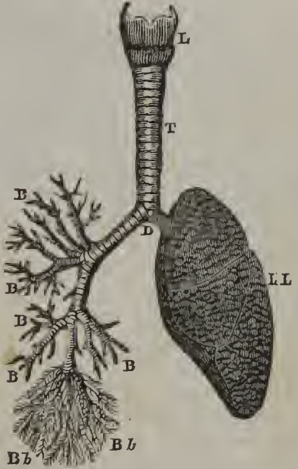
46. The organs devoted to the purpose of purifying the blood are the *Lungs*, which are two large bags situated in the chest, one on each side, and nearly filling up all those parts of that great cavity not occupied by the heart and large bloodvessels. It has been already stated, that the right side of the heart is devoted exclusively to sending the blood into the lungs (10). All the blood that flows into them (except a small quantity of arterial blood for the nourishment of their substance) is, of course, venous or black blood. The veins from the body empty their blood into the right side of the heart, and thence it goes to the lungs; in them it becomes changed from black to a vermilion colour, and then is transmitted to the left side of the heart, to be distributed through the body.

An intimate connexion, therefore, exists between the heart and the lungs.

47. The purification of the blood is effected by a chemical interchange of properties between it and the atmospheric air which enters the lungs during respiration. For this purpose the two are brought into very close communication with each

other, in the following manner. Each lung is formed of an extremely fine and delicate membrane, in the form of a large sac, the cavity of which is made up of a countless number of very small cells, called *air-cells*, which are filled with air on inspiration. Each air-cell is accompanied by a capillary artery and vein, which are the final ramifications of the pulmonary artery and pulmonary vein transmitting the blood from and to the heart.

Fig. 13.



A view of the Trachea and its branches, with one lung attached. L, the larynx, at the upper end of T, the trachea. D the point of its division into its two main branches, called bronchiæ. L L the left lung. The two lines on its surface mark the fissures which separate it into three parts, called *lobes*. B B B B B are ramifications of the right bronchus. B *b* B *b* show their final terminations. Each little vessel opens into an air-cell.

The air gets into the lungs through the windpipe T,* a tube situated in the throat, and running from the back of the mouth to the upper end of the breast-bone behind, at which point it divides into two branches, one of which goes to each lung. Each of these branches, when it reaches the lung, divides again, and these subdivide into minute ramifications, which finally terminate in the air-cells.

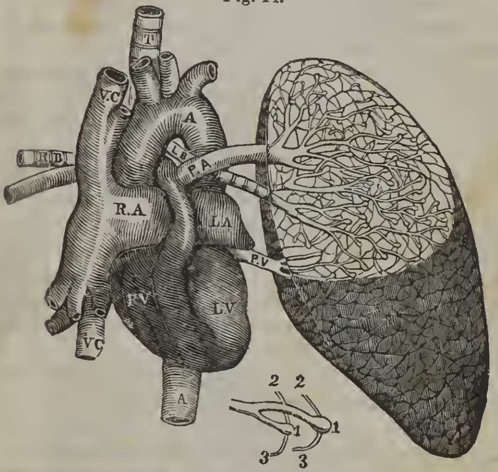
A pretty good idea of this arrangement may be had by supposing a large tree in full foliage, having two large main branches, and cut off at the earth and inverted. The trunk of the tree will represent the windpipe; at a short distance from the end it divides into two principal branches; these again divide into other branches; and this division and subdivision is carried out so far that each branch finally terminates in little twigs; and at the end of each twig is a leaf, the great numbers of which cause the tree to seem as if made up wholly of leaves. The leaves represent the air-cells. So it is with the lungs. As the windpipe and bronchiæ divide and minutely ramify until they terminate each in a little cell, it appears as if the lungs were totally composed of these air-cells.

48. Upon very close inspection of the organs themselves, it will be seen that around each air-cell circulates a number of fine capillary bloodvessels, some bringing black blood and others carrying bright red blood away. The blood circulates freely through these little vessels in contact with the membrane forming the cell, and in its passage through the vessel its colour is changed

* Technically called the *Trachea.*

by the chemical action of the air in the cell. The *blood* does not come into immediate contact with the *air*, but they are separated only by a membrane so fine as to oppose no impediment to the necessary chemical operation.

Fig. 14.



The heart, with the left lung in connexion. The upper half of the lung is divested of its external membrane, to show its internal structure. T the trachea. L B, its left branch, the extremities of which terminate in the air-cells. P A, the pulmonary artery, P V, the pulmonary vein ; the former, by its capillary terminations, taking the venous blood *to* the air-cells, and the latter, by its capillaries, taking the red blood *from* the air-cells. The lower half of the lung presents its natural appearance as seen in a healthy subject. 1 1, a magnified view of the air-cells. 2 2, capillary arteries going to the cells. 3 3, capillary veins running from them.

Before entering into an explanation of the inter-

esting chemical actions which take place in the lungs, we will examine the beautiful and ingenious mechanism by which the atmospheric air gets into the chest, and it will be seen that the *physical* part of the operation is arranged and conducted in perfect accordance with well-known pneumatic laws. Our admiration is excited as much by its simplicity as its perfect efficiency.

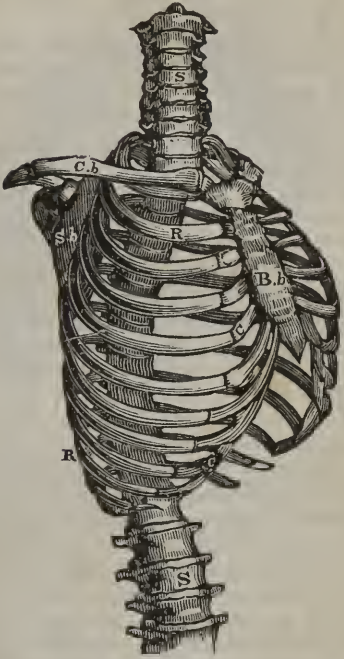
49. The human body contains three great cavities: first, that of the head; second, that of the chest; and, third, that of the abdomen. The first of these is filled with the brain and its apparatus; the last, principally with the organs of digestion; and the second, the chest, contains the heart and the organs of respiration. These three cavities are totally distinct from each other in their boundaries, and although they have a very close *vital* connexion, they may, for the purpose of exhibiting their mechanism, be considered as entirely independent of each other.

The chest will comprise, therefore, all with which we have at present anything to do.

50. This great cagelike cavity is made up *behind* by the middle portion of the spinal column, at the *sides* and *top* by the ribs, in *front* by the breast-bone, and *beneath* by a broad muscle called the diaphragm. These constitute all the boundaries of the chest; and it will be seen, by reference to the figure below, how ingeniously the space is made as large as is compatible with its strength, and the graceful proportions of this part of the body (fig. 15).

S S represents the spine or posterior boundary of the chest. R R, the ribs, which are fastened by

Fig. 15.



C b the collar-bone, S b the shoulder-blade.

one end to the spine, and, making a large curve, go forward to be attached to B b, the breast-bone. The ribs do not touch the breast-bone, but are fastened to it by means of strips of cartilage, C C C,

which give to the chest much freedom of motion and great elasticity.

There are twelve ribs on each side, but they are all of different lengths, the shortest being at the top, and having the smallest curves; as they descend, they increase in length till the seventh, which is the longest. From the seventh to the twelfth they decrease in length, the cartilages becoming longer in proportion, except the last two, which have no cartilage and no attachment other than at the spine.

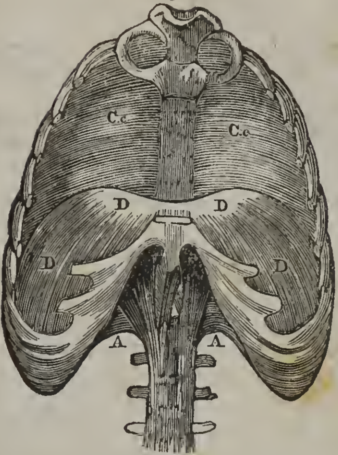
The ribs are attached to the spine by a joint which is slightly moveable.

By examining the preceding figure, it will be observed that the ribs do not lie horizontally, but their front ends are much lower than their hinder ends; they run downward as they run forward. This is an important point in the mechanism of respiration, and must be particularly recollected.

51. The next part of the apparatus to be described is the *Diaphragm*. This is a broad sheet, composed of muscle and tendon, of a circular form, and completes, when in its natural position, the lower boundary or floor of the chest (fig. 16).

The circumference of this circular muscle is attached to the inside of the front ends of the ribs, to the lower end of the breast-bone, and to the spine behind. It does not lie *flat*, but its centre is pushed high up into the chest, so as to form a great convexity in that cavity, and a concave surface on the under side. It forms a complete separation between the chest and all the parts below it, except where it is perforated by the large bloodvessels and

Fig. 16.

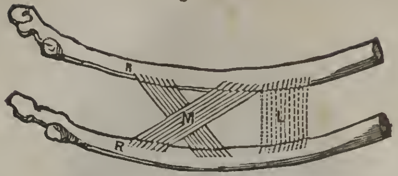


The front half of the ribs being cut away, the interior of the chest is exposed. C c C c, the cavity of the chest, empty. D D D D, the diaphragm, rising high in the centre, and descending very low at the sides and behind. The white space at its upper part is its tendinous portion. A A, the abdomen.

nerves, which pass up and down, and by the œsophagus or food-pipe, which goes through it into the stomach.

52. To complete the walls of the chest, there remains now only to be shown the filling up of the spaces between the ribs; and this is effected in such a manner as to add very considerably to the respiratory power of these organs. All those spaces are occupied by strong muscular fibres, whose arrangement and uses can be best explained by a figure (fig. 17).

Fig. 17.



R R will represent sections of two ribs, and M will show the direction of the two sets of muscular fibres which run from one to the other.

There are two layers of muscles placed between the ribs, whose fibres cross each other, as in the cut. These muscles fill up entirely all the spaces between the ribs, and their object is to bring the ribs closer to each other by their contractions, an object much more readily gained by this arrangement of the fibres than if they went directly from one rib to the other in the direction of the dotted lines L.

The reason is obvious; for if they can only contract one third of their length, which is believed to be the maximum extent with any muscle, the perpendicular fibres would be able to bring the ribs only that much nearer together; whereas the *oblique* fibres, with the same degree of contraction, by acting together, will nearly close the intervening space. This affords another striking proof of the ingenuity of the designer of this curious mechanism.

53. Most people who have not given much thought to the subject, would answer, if they were asked to explain how the air gets in the lungs, that they supposed the air *rushes in at the mouth and*

pushes the ribs out, and so the lungs become filled. And then if they are told that if the mouth were held wide open a whole day, and no exertion made, no air would go in, they would probably be unable to tell anything about it. They might with as much truth say, if a pair of bellows were lying untouched on a table, the air would rush in through the nozzle and push the boards asunder.

But every one knows, that if the boards of the bellows are *pulled* apart, then, in obedience to a well-known law of pneumatics, the air goes in through the valve and nozzle, and occupies all the space between them. And when the boards are pressed together again, the air is forced out through the proper opening.

Such is precisely the manner in which the air is made to enter the chest. This cavity is first greatly enlarged, by which a vacuum is produced, which vacuum is instantly filled with air entering through the only opening there is, viz., the mouth, which leads to the windpipe. The air is thus said to be *inhaled;* and when the chest contracts its dimensions, the air is forced out at the mouth, and is *exhaled.* The alternate expansion and contraction of the chest are not merely passive operations, but are both produced by the action of a powerful set of muscles, called *respiratory muscles,* of which the diaphragm and the muscles between the ribs form an important part.

54. The enlargement of the chest is made in three directions. First, the diameter from side to side is increased; second, the diameter from the spine to the breast-bone is also elongated; and,

lastly, the length from top to bottom is very much extended.

The first enlargement is produced simply by elevating the sides of the ribs. The spine is the fixed point upon which all the motions of the ribs are made; and by referring to fig. 15, it will be perceived, that if a rib is raised and turned a little on its joint at the spine, in consequence of the peculiar direction of the rib before noticed, the middle portion of it will be thrown farther from the centre of the chest, and, consequently, the two sides of the chest will be farther separated from each other.

Secondly, by the same elevation of the ribs, their front ends are brought more on a line with their other ends; and to permit this motion, the breastbone must be raised and pushed a little forward. Any one may be convinced of the first of these motions by placing one hand upon each side, and feeling the elevation and protrusion of the ribs; and of the second, by laying his hand upon his own breast, or looking at another's. The motion of the bone may be distinctly seen, but more especially after severe exercise, as running, when the breathing is "hard." These motions are commonly called the "heavings of the chest."

55. The enlargement of the chest from top to bottom (the third) is produced solely by the diaphragm, without any active aid from the ribs. This organ has been described (51) as situated in such a manner that, when in a state of relaxation, it forms a convexity within the chest, and is very concave or hollow underneath. It is, in fact, shaped like a dome, or an upper segment of a hollow

globe. When the fibres of the diaphragm contract, its centre is brought down nearer to a line with its circumference; in a word, it is partially *flattened.* This organ being the floor of the chest, of course, by being thus lowered, it leaves more room above it; and it adds very materially to the size of the chest.

Fig. 18.

Sections of the chest, diaphragm, and abdomen.

These cuts represent, in section, the different positions of the diaphragm in its conditions of relaxation and contraction, and also the different corresponding conditions of the abdomen and chest. In No. 1, D, the diaphragm is greatly contracted,

whereby the chest is enlarged, and the abdomen, M M, is protruded. In No. 2, D D, the diaphragm is relaxed, and the chest and abdomen correspondingly altered in size and position.

56. Now all the motions above briefly described take place simultaneously. The first two are produced by the action of strong muscles placed outside the chest, aided by those between the ribs; and these and the diaphragm all acting together, they have a great effect in increasing the capacity of the cavity within.

This great enlargement produces, as has been said, a vacuum within, which is supplied as soon as made, by the air rushing in at the mouth.

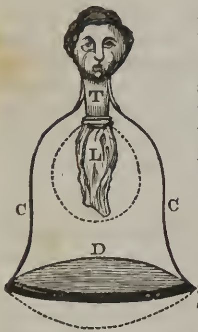
57. But it must be recollected that the air which enters the chest does not get into the cavity itself, but into the air-bags or lungs within the chest. These have no power of themselves to expand, being made simply of fine membrane, without a particle of contractility like muscular fibre ; but, as the chest enlarges, the air rushes into *them*, and swells them out so as to fill up the cavity.* If an opening should be made in the lung to communicate with the cavity of the chest, then some of the air which enters the lung would get into the chest, and the lung would not so fully expand. Very unpleasant and dangerous symptoms would be the result of such an accident.

58. To explain more clearly the mode in which air gets into the lung, a little model is frequently

* By placing one's ear against the chest of a healthy person, the noise made by the air passing through the lungs may be distinctly heard in a quiet room. The sound of the action of the heart may be perceived also, if the ear is placed over that organ.

exhibited, of which the figure in the margin is a representation.

Fig. 19.



C C is a bell-shaped glass to represent the chest. In the mouth of the glass is inserted very tightly a cork, T, representing the trachea, having a hole lengthwise through it. To the lower end of the cork, before it is put in its place, is tied a small bladder, L, to represent a lung. The lower end of the bell is closed by a piece of sheet gum elastic, D, which is closely pasted around the edge so as to be perfectly air tight. This answers for the diaphragm. It is clear that no communication exists between the cavity of the bell and the external air, except through the hole in the cork, and any air entering through that hole can only go into the bladder. It is evident, also, that when the diaphragm is pushed up into the cavity of the glass, as at D, the bladder will be flaccid and void of air; but when the diaphragm is pulled down in the situation of the dotted lines, a partial vacuum in the glass will be the consequence, which can only be supplied by air through the cork, which will expand the bladder to its full extent, shown by the dotted circle; and when the diaphragm is pushed up again, the air will be forced out from the bladder.

To complete the model, a hollow paper doll's head may be placed on the cork, having the

mouth communicating with the bladder. By varying the size of the mouth, different sounds, as of breathing, whistling, &c., may be produced, and a candle may be blown out by it.

The diaphragm in the living body does not descend so low as in the figure, for much motion is required from it in the latter to compensate for the absence of expansion in the other parts. In the body, its centre does not descend to a level with its circumference. With this instrument, the model of only one lung can be shown, but it gives us the advantage of *seeing* its action.

59. It has been stated that the object of the lungs is the purification of the blood; but this is not the only result of their operations. It is doubtless owing to the chemical action continually going on in them, that the body is indebted for the constant maintenance of its uniform, elevated temperature. One of the most curious results of animal action is, that the body, under the greatest variety of external circumstances, is always found to have a temperature of 98° of Fahrenheit's thermometer. Whether we inquire of the inhabitants of India, living under the scorching rays of a tropical sun, or of the frozen regions of Labrador or Iceland, where they are surrounded with eternal snows, we shall find the temperature of the body to be invariably the same. The lungs are the furnace where the necessary caloric is *developed*, and from which it is distributed through the system; but the principal *regulator* of the temperature is the skin, an organ to be described hereafter.

60. Many different theories have been suggested by physiologists to account for the change in the

colour of the blood, and for the evolution of caloric; but we shall only attempt to explain the one which is the most probable.

Chemistry teaches us that atmospheric air is composed of two distinct elementary gases, whose properties are very different. They are called *nitrogen* and *oxygen*. The former constitutes about four fifths of the air, and the latter one fifth. Nitrogen gas, when pure, possesses no active properties; it will not support either combustion or animal life, nor will it destroy either by any peculiar power of its own. On the contrary, pure oxygen has many active and powerful properties. Bodies not commonly inflammable will burn in it with great rapidity and brilliancy, and animals live in it with increased activity; but they cannot live so long in it as in the open air. They die sooner, as they seem to live faster.

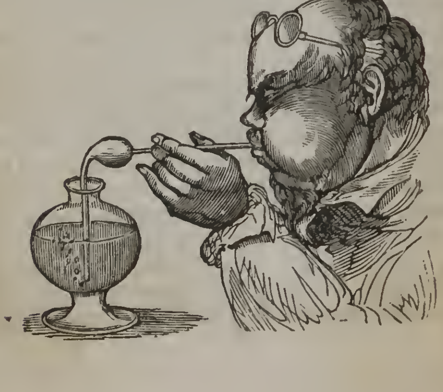
Oxygen is, in fact, the *vital principle of the atmosphere*, and without it, combustion and life would both be extinguished. It is supposed by some that the nitrogen is combined with it principally to *dilute* it, to render it less active, but *not* to *destroy* any of its qualities.

61. Oxygen is the principal material which, when received into the lungs, causes the change in the colour and properties of the blood, and developes the requisite caloric. The venous blood owes its dark colour chiefly to the presence of carbon, another simple substance commonly known to us as charcoal, which is chiefly pure carbon. Animal bodies contain a good deal of carbon in a subtile form; and it is well known that oxygen has a powerful affinity for it, and will generally unite

with it to the exclusion of other substances. The product of such a union is another substance called *carbonic acid* gas. When charcoal burns in the open air, this gas is produced; and being a very deleterious and poisonous substance, fatal consequences often ensue to those who breathe it. It is easily proved that this gas is formed in animal bodies during the process of respiration; and as it can only be formed by the combination of oxygen and carbon, and as we can show that all the oxygen which is inhaled does not return as oxygen, but in the form of carbonic acid, the fair inference is, that it has taken carbon from the blood. We inhale nitrogen and oxygen in the form of atmospheric air, we exhale nitrogen and carbonic acid gas. The oxygen, therefore, must have quitted the nitrogen and combined with the carbon.

To prove that carbonic acid is contained in the exhaled breath, it is only necessary to blow it a few minutes through a small tube immersed in clear

Fig. 20.



lime water contained in a vial. The gas has a strong affinity for lime; and, when passed through that liquid, it unites with the lime, forming a light powder, which is insoluble, and gives to the fluid a cloudy appearance (fig. 20).

62. Besides this gas, there is thrown off from the lungs a large quantity of watery vapour, amounting, as is estimated by some, to twenty ounces in twenty four hours. The fact that a large quantity is expired with every breath, may be proved by breathing upon a cold polished surface, as of glass or metal. The vapour condenses, and rapidly accumulates in drops.

63. The dark blood being in this manner deprived of its carbon, it must be apparent to any one who thinks a moment upon the subject, how important it is to a healthful action of the lungs to have a free supply of fresh air. Almost everybody can testify, from their own experience, to the disagreeable effects produced by confinement for a length of time in a close room, especially when a number of individuals are collected therein. Each person respires about twenty times a minute, and takes in at every breath about forty cubic inches of air (rather more than a pint), the oxygen of which is not only nearly all used up, but forms part of a substance as positively injurious to health, as are the fumes of burning charcoal. When, therefore, a number of persons for a long time breathe the same atmosphere, without any ventilation or renewal of it, they rapidly exhaust the air of its healthy properties, and subject themselves to great dangers. The reason is this: No pure, fresh oxygen being admitted to the lungs, the dark blood

cannot part with its carbon, because this gas is the only means by which it can be taken away. The blood, therefore, does not become revitalized; it has to go back to the heart from the lungs in its impure state, and it is sent through the body totally unfit to give it proper nourishment. The whole system partakes of the injury; the brain and spinal marrow, which are the centres of the nervous power, become unable to discharge their high functions properly; the action of the heart and lungs becomes thus still farther impaired, and so, directly and indirectly, the entire body becomes rapidly surcharged with vitiated blood, and, unless speedily relieved by the admission of fresh air to the lungs, fatal results must ensue. Persons who have been sitting several hours in a crowded church in cold weather, when the doors and windows are all closed; even children confined for five or six hours in a close schoolroom of small dimensions, without ventilation, as is the barbarous practice in too many places in city and country, exhibit the depressing effects of imperfectly decarbonized blood in their drowsiness and the general torpor of the body. They perceive the striking difference between good and bad air—between that which contains plenty of free oxygen, and that which contains but little—when they emerge from their confinement and inhale the first draught from without. The spirits immediately revive, and new strength seems imparted to the body.*

* It was once remarked, that in Scotland they formerly had long sermons against "the sin of sleeping in church," but by increased knowledge it had been found out that a perfect ventilation of their churches did more to keep people awake than all the sermons illustrative of the sin of "church sleeping.'

64. Among the numerous instances of danger and suffering from confinement in an atmosphere vitiated by passing repeatedly through the lungs, the occurrence at the "Black Hole" of Calcutta is one of the most memorable and melancholy. In 1756 the city was reduced by Surajah Dowlah, and 146 English prisoners were forced into a dungeon about eighteen feet square. The only opening to the air, except the door, was by two windows on the west side, strongly barred with iron. In a few minutes a profuse perspiration burst out upon every one; a raging thirst ensued. In less than an hour after their confinement, their thirst was intolerable and respiration difficult. Many soon became outrageous, and insulted the guards to induce them to fire in upon them. "Water, water," was the general cry; but, when brought, it only served to aggravate their distress. The confusion became general, and amid horrid cries and ravings for water, some were trampled to death. In less than three hours, most of the gentlemen were dead; and in half an hour more, most of the living were in an outrageous delirium. They found that water heightened their uneasiness, and "air, air," was the general cry. All the opprobrious names that the viceroy and his officers could be loaded with, were repeated, to provoke the guard to fire upon them. Every man had eager hopes of meeting the first shot. Having been shut up at about eight o'clock in the evening, the door was opened at six the next morning, when only twenty-three, the poor remains of 146 souls, came out alive, but most of them in a high putrid fever.

65. In connexion with this subject, there is another which deserves some attention, as it affects

the health and lives of many individuals in as great a degree as this.

Tho lungs have been described as two large sacks of extremely fine texture, filling up by their size *every particle of the space between the ribs* not occupied by the heart, the large bloodvessels, and the membranes covering them. They can receive no more into them than is sufficient to supply the increased capacity produced by the enlargement of the chest. The respiratory muscles enlarge the chest to a certain extent, and a quantity of air just sufficient to fill the chest, but *no more*, enters the lungs. All that we can possibly get is necessary to purify the blood thoroughly; and if, by any cause, the requisite quantity of oxygen is prevented from reaching the lungs, the system feels very soon the effects. Those who live in the crowded, smoky, and dusty atmosphere of a populous city, experience this. So much of the air is unfitted for respiration, that there is not a proportionate quantity of oxygen taken in at each inspiration, and very frequently through the day, unconsciously, in general, to the individual, nature instinctively makes an effort to compensate for the deficiency by producing one or more deep and copious inspirations. How often is heard from the citizen, when he first enters the pure atmosphere of the country, the exclamation, "How much *easier* it is to breathe!" Less labour is there really required from the respiratory apparatus, because the dark blood is more rapidly and effectually decarbonized.

66. If, then, *pure* air is so essential to the healthy operations of the lungs, what must we think will be the effect of preventing their expansion and of *to-*

tally excluding from them a large proportion of the air which they might have. We have shown the chest to be a flexible elastic cage; a considerable portion of its walls is made of elastic cartilage, which will readily yield to pressure (fig. 15). The object of these cartilages is principally to assist in bringing the chest to its former size, to produce *expiration* after it has been enlarged in inspiration. Their flexibility may be proved by placing a hand on each side and pressing them together; the sides can thus be made to yield several inches. The most cursory observer must therefore perceive, that if a bandage is tightly drawn around the chest, and continued there for hours, not only will the chest be prevented from fully expanding by the confinement of the diaphragm as well as the ribs, and a great quantity of air be shut out from the lungs, by which the venous blood will be unable to give off all its carbon and other impurities, but the right side of the heart must labour harder to propel the blood through the constricted lungs, and the left side also to keep in motion a fluid less suited to its action. The delicate valves have an unnatural duty to perform; and, finally, apart from the distressing palpitations almost universally experienced by those who yield to such habits, enlargements of the heart, thickness of the valves, consumption, and a long train of painful disorders ensue to imbitter and shorten their days. Nature, or, rather, the wants of the whole system, endeavour to compensate for the artificial privation by increasing the exertions of the respiratory organs; the chest is compelled to a great *frequency* of action, and

hence inflammation of the lungs is often another result.

67. This is not all. We have already alluded to the effect produced by undecarbonized blood upon the brain, the seat of the intellectual faculties, clouding and obscuring its operations. Several other evil effects are felt by this organ, but they must be considered in more appropriate places.

It is bad enough to be obliged to breathe a vitiated atmosphere, but to exclude the delicate lungs from the use of even that, to deprive the impure blood of a part of that restoring power, imperfect as it is, and to drive the already overburdened heart to still greater efforts, is a practice baneful to the health, destructive to the intellect, subversive of the morals—it is *suicidal.*

68. To exhibit more distinctly the effect upon the conformation of the chest, from the barbarous practice of "tight lacing," the accompanying figures are subjoined. There is no exaggeration in these outlines. Such melancholy specimens are daily to be met with, both living and dead.

No. 1, fig. 21, is an outline of the famous statue of the Venus de Medici, and may be considered as the *beau ideal* of a fine female figure.

No. 1, fig. 22, is part of the skeleton of a similar figure, with the bones in their natural position.

No. 2, fig. 21, is an outline of a figure of a modern "boarding-school miss" after it has been permanently remodelled by stays.

No. 2, fig. 22, is the skeleton belonging to such a figure.

What individual, laying the least claim to a refined and correct taste, can hesitate for a moment

Fig. 21.

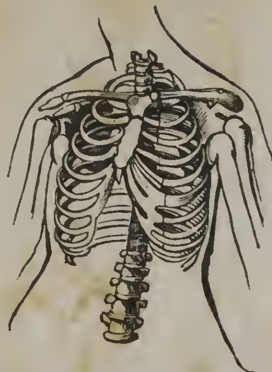
1

Outline of Venus de Medicis.

2

Outline of the form of a modern Belle.

1



The skeleton as Nature formed it.

2

The skeleton as Art has deformed it.

to give the most decided preference to the former of these as the "finest figure." It is true, it does not accord with the views of the *fashionable* world, but if that class of people must torture and twist some part of their bodies, far better would it be for them to apply the screws to the feet, as do the Chinese, than to the chest. Such a "fashion" would be no more absurd, less uncomfortable to the individual, and less dangerous to life.

69. The aqueous vapour which is exhaled in such large quantities (62) from the lungs, is believed to be also produced by the agency of oxygen. One of the impurities of venous blood is supposed to be another gas, called hydrogen, which is well known to have a strong attraction for oxygen, by which water is formed; that fluid being composed solely of these two gases.

70. To these two chemical operations, viz., the formation of carbonic acid and of water, are supposed to be attributable the evolution of the heat necessary for the system. Increased specific caloric is an invariable effect of these combinations out of the body, as every chemist knows, and there is no good reason why it should not be so in the lungs. It is true that the lungs are not any warmer than the most distant part of the body, as might be supposed would be the case; but it is to be recollected that the circulation of the blood through the chest is three times more rapid than the respiration, i. e., the heart pulsates three times, and sometimes more, to one expansion and contraction of the chest. The caloric which is generated there is therefore carried away as fast as formed,

and distributed by the blood equally through the entire system.*

* This is the rationale given to the process of calorification in the animal body by many distinguished physiologists; but there is another view of the mode and situation in which it is carried on, which is in many respects equally plausible.

Carbon is supposed to be set free in the blood principally by the conversion of *albumen* into *jelly*, a process which takes place all through the body, but more particularly in the skin, through the agency of the capillary arteries.

Jelly is well known to form a large constituent of the skin of all animals. The oxygen taken in at the lungs is supposed to enter into the blood in a state of loose combination, and to be carried through the system, uniting with the disengaged carbon in the capillary circulation, and the carbonic acid to be conveyed by the veins back to the lungs to be exhaled. The combustion of carbon and oxygen is thus made to impart its caloric immediately at the spot where it is wanted, and the main fire that supports the temperature of the body is placed where it is most needed, at the external surface.

CHAPTER III.

VOCAL APPARATUS.

71. Connected with and depending upon the function of respiration, is another highly curious and interesting mechanism now to be described. It is an instrument of very delicate and somewhat complex construction, and is adapted to several uses, or, rather, to a variety of modifications of the same office. In infancy, it is an instrument by which the child can make known to the parents its wants; by which alone it is able to apprize them of its suffering when in pain, and to warn them to bring relief. In later life, it is an organ by whose agency individuals are enabled to make known to others their thoughts and feelings, with most unerring precision; it is, in fact, the great outlet of the workings of the mind. It is, finally, an apparatus capable of producing the most exquisite music. It may rival the flute in softness of tone; its shrillness is not surpassed by the "ear-piercing fife;" its mildness may equal the clarion's; and in mellowness of note or soul-stirring energy of sound, the trumpet does not approach it.

72. This instrument is composed of several parts, which, when all are considered together, are called the *Organs of Voice*. One part of the apparatus operates as a stringed instrument, like the Eolian harp. The latter is made simple by stretching a

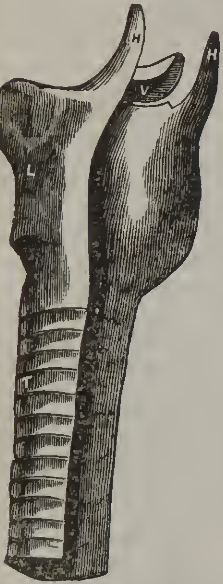
fine thread of silk across a board, about an inch above it, and placing it in the window-frame, with the sash brought down so as nearly to touch the string. As the breeze passes through the open space, it strikes the string and causes it to vibrate, by which a variety of musical sounds are produced. Another part of the vocal apparatus acts on the same principle as a valvular wind instrument, such as the valve trumpet or the common flute; or, as it has a pair of bellows (the chest) to force air through the instrument, it may be said to act like a church organ.

73. The windpipe, which has been described as the tube through which the air passes to the lungs, lies in the forepart of the throat. It is formed chiefly of cartilage, which, at the lower two thirds of its extent, is seen in the form of *rings* (imperfect behind), which may be felt in the lower part of the throat. These rings, being elastic like all cartilage, serve the very necessary purpose of keeping the tube always open, that no impediment may exist to the passage of the air. They will yield to pressure, but will instantly recover their natural form when the pressure is removed; at the same time, the flexibility of the tube will accommodate it to any position of the neck.

This tube is surmounted by a triangular box, also formed of cartilage, the greater prominence of which, in the man, produces the striking difference in the shape of the neck of the two sexes. This box is called the *Larynx*. The prominence in the neck formed by the larynx is commonly known by the name of Adam's Apple; from an old story that, when Adam swallowed the forbidden fruit, it

stuck in his throat, and is thus transmitted to his posterity as a memorial of his fall.

Fig. 23.



T represents the upper portion of the trachea or windpipe, formed of imperfect rings. The open space behind is filled up by a muscular membrane. L is the larynx, forming the upper end of the windpipe. H H are the two ends of a bone, which is shaped like the letter U, with the ends turned up. This bone is placed at the upper edge of the larynx, and serves to keep it stretched constantly open, and also for the attachment of several muscles.

The upper opening of the larynx is a simple slit or chink about three fourths of an inch long and one fourth wide. At the lower part of this chink are found stretched across two fine ligaments, which are directly in the current of air as it goes through the tube either way. These ligaments, by appropriate little muscles, may be relaxed or made tense, and being thrown into very rapid vibrations when the air rushes through them, produce every variety of sound.

74. The top of the trachea opens above into the

back part of the mouth, just in front of the opening of the tube leading to the stomach. All the food and drink, therefore, which we swallow, before it gets to the stomach tube, must pass directly over the top of the larynx. As even a small particle of food produces very distressing symptoms when it happens to get into the wrong passage, the larynx is most beautifully provided with a means of protection. Directly over the chink just described is placed a little valve, marked V in fig. 23, which shuts down over it the instant anything touches it, and closes the opening completely, so that the food passes by it into its proper place. Sometimes, when a person is eating very fast and talking at the same time, small particles of food will get into the windpipe ; this tube being lined inside by an exceedingly sensitive membrane, pain and suffocating symptoms are produced, the chest is thrown into violent spasmodic action called coughing, and generally the offending substance is thus thrown violently out, and the distress ceases. Sometimes it happens that a small substance, as a grain of wheat, a shot, a fruit-stone, or a particle of food, gets very far down into the windpipe, so that the individual is unable to cough it up. A train of terrible symptoms then generally ensues, terminating sooner or later in a painful death. Many children have lost their lives in that way, and neither infants nor aged should ever be in the practice of keeping small articles of unyielding substances in their mouth, for fear of such an accident.

The other part of the vocal apparatus is the mouth, comprising the cheeks, tongue, teeth, and lips.

The tongue and lips particularly act, as occasion requires, like valves or stoppers, changing the size and position of the orifices through which the air passes out, giving rise to most of the varieties of intonation and cadence in speaking.

CHAPTER IV.

OF THE BLOOD.

75. The investigation of the circulating apparatus which we have just completed, leads us very naturally to inquire more particularly into the nature of the fluid which it is the province of the vessels to convey through the system. Of all the liquid materials known to man, the Blood of animals is not the least, if it is not the most, remarkable. Of a peculiar colour, distinguishing it from all other fluids, it possesses a *variety* and *multiplicity* of properties altogether unrivalled. There are many fluids which exhibit more strikingly *energetic* qualities, such as the corrosive mineral and vegetable acids, &c.; but we shall perceive that the blood, when acting its peculiar part in the animal economy, is capable of distilling, as it were, from itself, a solvent (the gastric juice) of more various and extensive action than any known acid.

76. The blood, moreover, is supposed to hold in solution, while in vital communication with the body, all the materials which are necessary to pro-

duce every tissue in the animal structure. The means by which it does this, or, rather, the laws through whose influence, whether chemical, mechanical, electrical, or other, this is effected, have hitherto entirely eluded the researches of the most expert experimenters and profound reasoners. That an almost innumerable range of materials unite to make up this singular fluid, is clearly demonstrated by its giving them forth continually and depositing them in their proper places; and yet the chemist can detect in it none other than well-known chemical substances. While it is known, also, that from the blood are developed matters the most discordant and opposite in character, such as water and oil; acids highly corrosive, and alkalies pungent; the inflammable phosphorus, and sulphur, and the incombustible soda or lime; the hard enamel, the tough tendon, and the delicate and tender nerve; a great variety in colour, as the black pigment of the eye, the white membrane, the red muscle, the yellow hair, and the iris as variegated as the rainbow; the dense bone, the semi-opaque nail, and the cornea, as transparent as the purest glass; the bitter gall, and the insipid saliva; while all these, and many other equally diversified properties, are known to be continually separated from the blood, this fluid itself presents, in its ordinary pure form, scarcely a trace of many of these properties. It only appears to us as a homogeneous fluid, of a uniform colour, slightly saline taste, innocuous to the touch, but when analyzed it is found to be complex in its chemical composition.

To facilitate the study of this unique substance, we may arrange its properties under three heads

or divisions, viz., *Physical*, *Chemical*, and *Vital*. Though in some points we may find the properties under these heads to assimilate, yet the distinctions, in the main, will be sufficiently obvious to justify such a classification.

PHYSICAL PROPERTIES OF THE BLOOD.

77. a. *Colour*.—In man and the higher order of animals, the blood, when first drawn from the circulating vessels, is of a red colour (except when distinguished as arterial and venous blood, 44, 45), having rather a soft vermilion tint. This colour is uniformly the same in these animals in a healthy condition, and is not subject to much change even by disease. When the respiratory function is disturbed, either from an inability of the chest to admit air, or from the admission of impure air, the decarbonization of the venous blood is imperfect, and the blood found in the arteries will partake more or less of the *purple* hue of that of the veins. But the characteristic redness of healthy arterial blood is always more or less distinguishable.

In some of the lower orders of animals, the blood is of a very different appearance; it is in them called *white blood*, being entirely devoid of redness, and almost colourless. With white-blooded animals, the muscles are also white, as with fishes, frogs, reptiles, &c.

b. *Consistence*.—Immediately upon being taken from the body, as is well known, the blood is seen to be a perfect fluid, nearly or quite as thin as water. This condition is necessary to it in the blood-vessels, that it may circulate through the intricate

mazes of the inconceivably minute capillaries, as well as through the larger arteries and veins, with the least possible obstruction. In the living, healthy body, there is very little more adhesion between the different particles of the blood in circulation than there is between the particles of water flowing through the conduit pipes of a city; and as long as the active motion of the blood is kept up, so long will it maintain its complete fluid form.

But when allowed to remain at rest for a short time, particularly out of the body, a remarkable spontaneous change occurs in the form of the blood. One part of it loses its liquid consistence, and falls to the bottom of the containing vessel, while the remainder retains its fluidity, but undergoes other important changes. This phenomenon is denominated *coagulation*. The process, as observed under ordinary circumstances, in an open vessel, commences with an apparently uniform thickening of the whole, and a gradual separation into two distinct parts, the one being a viscid, heavy mass of a red colour, and the other a thin, watery fluid, colourless, or, perhaps, slightly yellow. The former is called the *crassamentum* or *clot*, and the latter the *serum*.

The *serum* is the fluid which is drawn from the body by the action of a blister.

When submitted to the action of heat or alcohol, it also coagulates and divides into two parts. One a dense matter, which resembles the white of an egg boiled hard; it is essentially the same substance, and hence is called *albumen*. The other part of the serum is a limpid fluid, denominated the *serosity*.

The average time required for the completion of

the coagulation of the blood is about seven minutes, in the open air.

The most accurate investigations have shown the average amount of the crassamentum to be about one third the weight of the serum.

If the blood, when flowing from an open vein, is received into a bottle, and violent agitation is given to it, the formation of the clot may be altogether prevented, especially if the temperature of the blood is kept at its natural elevation.

On this account as well as others, we may see the necessity of maintaining the activity of the circulation by frequent exercise, and of avoiding such a course of living as will tend to thicken, and thus retard, the motion of the blood. The Asiatic Cholera, when it appeared in this country a few years since, was characterized by a remarkable torpidity of the circulation and coagulated state of the blood. The serum was usually discharged in enormous quantities from the skin, kidneys, and bowels, leaving behind only the crassamentum, which could not pass freely through the vessels, and the circulation was thus greatly impeded.

Rest, therefore, seems necessary for the success of the process of coagulation. *In* the living body, as well as without, the blood will undergo this change, even without any reduction of its temperature, if all motion between its particles is suspended. This occurs in the surgical disease called *Aneurism*, which is an enlargement of an artery, forming a hollow tumour, filled with blood, by far the largest portion of which does not circulate freely. It happens, also, when a bloodvessel becomes ruptured near the surface of the body, let-

ting out a small quantity of its contents, which, being unable to escape entirely, coagulates around the opening in the vessel, and forms a kind of plug, which checks any farther bleeding.

When the clot is minutely examined after being removed from the serum, it appears under the form of a soft solid, sufficiently firm to bear cutting with a knife. It retains all the red colouring matter of the blood, and this, by repeated ablution in water, may be entirely separated from it, leaving the clor of a clear white, showing the union to be merely mechanical, and not dependant upon any chemical affinity. The white mass remaining is called *fibrin*, and very closely resembles the pure muscular fibre.

Fig. 25.

Fibrin of the blood.

The cause of the coagulation of the blood has never been satisfactorily explained, and the laws which regulate it are not yet known to us. It is a phenomenon to which we are acquainted with nothing exactly similar; but especially are we unable to understand the reason why many causes of

sudden death entirely prevent the process: as lightning and electricity, a blow upon the stomach or chest, an injury of the brain, bites of poisonous animals, and violent mental emotions. These, when they produce the sudden extinction of life, prevent the usual coagulation of the blood.

It is upon the fibrin that the property which the blood possesses of repairing injuries of the solids of the body principally depends, a property which affords one of the most interesting examples of the resources of the animal economy. When an incision or laceration of the body happens, the blood issues from the divided vessels, fills up the wound, and then coagulates, unless a very large vessel should be wounded, and the blood flow too rapidly and escape. The clot remains, while the serum evaporates. *Organization* then takes place in the fibrin; that is, new bloodvessels are formed in it, connected with the adjacent old ones; new nerves also are produced through it, and it soon becomes a living mass. Rest and quiet are all that nature requires to complete this process; the simplest dressing to a common wound is, therefore, all that is required. In former times, a common practice was to apply a sympathetic powder to the instrument which produced the wound, and merely bind the latter up. The cure was then attributed to the action of the powder on the instrument, and that superstitious notion was believed in a long time, and until it was discovered that the wound would do just as well without dressing the instrument. The true secret consisted in keeping the wound quiet.

c. *Temperature.*—The circumstance of the

maintenance of the temperature of the blood at a uniform standard, 98°, under the greatest changes of climate and the most varying conditions of the external world, is among the most curious of the phenomena of this wonderful fluid. The cause of its elevated warmth, and the reasons of its uniformity, are noticed at more length in the chapters on respiration and the skin. The temperature of white-blooded animals is much below that of the red-blooded; they are hence called "cold-blooded" animals.

d. *Quantity.*—The amount of blood in different individuals varies considerably; and it is a very difficult matter to arrive at a satisfactory conclusion of the average quantity, principally for the reason that there is no mode by which the actual amount in any one person can be ascertained. Taking all circumstances into consideration, it is believed that the blood constitutes about one fifth of the whole weight of the body. A man of 150 pounds, therefore, would have about thirty pounds of blood. In infancy, the proportion of fluids is much greater; and in old age, less.

e. *Weight.*—The specific gravity of the blood is rather greater than that of water, being about 1.050. The serum is also denser than water. Its specific gravity is 1.025. The difference between water and crassamentum is stated to be still greater; the latter has a specific gravity of 1.126.

CHEMICAL PROPERTIES OF THE BLOOD.

78. The number of chemical substances discoverable in the blood itself, when subjected to the action of reagents, is very great, and yet the

ablest chemists have been unable to detect in it many substances which are known to exist in other parts of the system, and which could only have got there through the medium of the blood. It is true that many chemical compounds may be actually formed from ingredients contained in the fluid, at the moment of their being deposited from it, in their respective places, and for this purpose some of the sanguineous constituents may be decomposed from one form, and recomposed into another at the same instant; for different proportions of the same ingredients, and even different modes of union between the same proportions of the same ingredients, are known to result in compounds of very different properties.

Moreover, there are some substances found in the blood whose presence cannot be accounted for satisfactorily. Being simple bodies, they cannot be produced by combination of other matters, and the source whence they are derived remains undetermined. Such is the iron, which is now believed to be the colouring matter of the blood. Recent experimenters have stated their belief, that in the blood of forty men there is iron sufficient to form a ploughshare.

79. Some experiments have been performed on the growth of plants, with a view of ascertaining, if possible, whether they would contain materials which could not possibly have been derived from the soil in which they grew or the water which nourished them. Seeds were planted in clean washed sand, sulphur, or some substance from which they could not be supposed to derive any extraneous matter, and were moistened with dis-

tilled water. They were found, nevertheless, after arriving at considerable growth, to contain materials which must have been derived, in part at least, from some action of their vital powers, and could not have been obtained from without. So it is with the blood of animals. It contains materials whose source is not understood; and other substances are produced from it, composed of matters of which no trace appears in it. There appear to be only three conceivable modes of accounting for this. "Either some of the bodies which we suppose to be elements, as, for example, oxygen, hydrogen, carbon, sulphur, or phosphorus, are in reality compounds, and are decomposed by the powers of life; or these are capable of converting the elements into each other; or, in the third place, there is a creation of absolutely new matter. The first of these suppositions is in itself by far the most probable."*

* This is the conclusion of some of the best physiologists. Perhaps the possibility of deriving those unexplained materials from floating particles in the atmosphere, so copiously inhaled with the air we breathe, has not been taken sufficiently into account.

OF THE VITAL PROPERTIES OF THE BLOOD.

Secretion.

80. Under this head is placed the power which the blood possesses of eliminating from itself all the various materials necessary to form the different and numerous tissues of the bodies. When speaking of the capillary circulation, it was observed that it was the province of that system to deposite from the blood, in every part of the animal structure, the new material, which was to supply the place of the old, which had become deteriorated or worn out, and also to remove the latter. When we consider how very numerous are the tissues of the body, constituting the bone, muscle, nerve, vessel, cartilage, marrow, tendon, ligament, nail, hair, skin, membrane, &c., we are not more astonished that one fluid should contain the elements of so many widely different compounds, than that each should be deposited in its own proper place, and in none other. Nor is our astonishment lessened on reflecting also that a great many *fluids*, all differing greatly from each other, should be derived from the same identical source; as the gastric juice, saliva, perspiration, bile, and mucus, the tears, humours of the eye and ear, &c. The process by which all these substances are given out from the blood is called *secretion*, which, in its original meaning, signifies a *separation*, as it was formerly supposed that the different matters existed already formed in the blood, and were merely *separated* from it by simple mechanical means, without undergoing any change in the act. Now, however, it is generally believed that during the process of

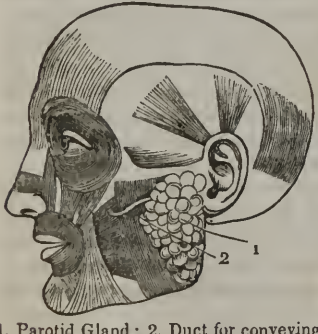
secretion, some change, of a chemical nature, takes place in the substance secreted, proceeding on the supposition that it did not previously exist already formed in the blood. The process of secretion, strictly defined, may therefore be said to be "that function by which a substance is separated from the blood, either with or without experiencing any change during its separation."

81. What a curious and highly interesting chemical laboratory does the capillary system of circulation present to us? Without the aid of furnaces, crucibles, acids, or any other reagents, from one uniform, homogeneous fluid, by its wonderful power, it decomposes the substance of that fluid, and recomposes the elements into a hundred other matters. Nor is this all. Never, in a healthy condition, does it make the mistake of elaborating a substance in the wrong place. Muscle is not deposited in the place of bone, bone in the place of nerve, nor bile in the place of tears. But each little operator, knowing well its duty, with unerring precision deposites each part in the place where its Maker first designed it to be. No confusion or interference is ever known among them, though not a particle of difference can be detected between them: each performs its appropriate work independently of all the others.

82. The function of secretion in many instances developes a complicated fluid, and we generally find in those cases an appropriate structure devoted to the operation; a body which is more or less of a rounded form, and hence called a *Gland*. Examples of such are the liver, which secretes the bile; the *kidneys*, which secrete the urine; the

sub-maxillary (under the jaw) glands, which secrete the saliva, and so on. Each gland is supplied with a number of little tubes to receive the secreted fluid, which unite into one larger tube, called the *Duct*, which conveys the fluid to its destination. There is a large salivary gland placed behind and beneath the ear, called the *Parotid Gland*, which communicates with the interior of the mouth by a duct about as large as a small quill, through which it discharges its saliva during mastication. It is so situated that the working of the jaw, in chewing, compresses it, and forces the fluid along to mix with the food. Young people frequently are affected with a swelling of this gland, called mumps. Many persons, in the act of gaping, often squeeze the gland so suddenly by the wide distension of the jaws, as to eject forcibly a little stream of saliva directly out of the mouth upon the book or paper before them.

Fig. 26.



1, Parotid Gland ; 2, Duct for conveying the saliva into the mouth.

There is a little gland placed at the outer and upper corner of each eye, which continually exudes a small quantity of liquid, which runs over the front of the eye, keeping it always moist, bright, and clean, and discharging itself through a canal at the inner

corner into the nose. When mental emotions of a sorrowful character arise, these little telltales soon give notice of it by pouring out a more abundant secretion, which, being too copious to be carried off by the regular mode, overflows the eyes, and runs down the cheeks in the form of tears. These are called the *Lachrymal Glands*.

83. The operation of secretion, which we have thus seen to be a separation from the blood of certain substances which are formed or produced at the moment of being deposited in their peculiar situations, is a process unlike any other known in nature. Almost every change wrought in the composition of the material world, if within the reach of the chemist, is capable of being understood and defined by him. From the formation of a dew-drop, and its oxydizing action upon an exposed cambric needle, to the phenomena of a volcano, or the motion of the planets in their orbs, the scrutinizing mind of the chemist and philosopher has discovered the true nature, or found a highly probable cause. His mental vision has even penetrated into the long-concealed truths of many of the operations of animal and vegetable life; but the real nature of the process by which the functions of secreting organs are conducted, has hitherto eluded his grasp. The delicate capillaries carry on the decompositions, recompositions, solutions, and precipitations in their laboratory, coextensive with the whole mass of the living frame, with the ease, quietness, and accuracy of the most expert manipulators, and man cannot discover the rationale of their processes.

The laws of chemistry, now so well established,

which apply with unvarying uniformity to the molecular operations of inanimate matter, are subverted and disregarded in many of the functional actions of the living body, and especially of those of the secreting functions.

The *principle of life*, superadded to the organization of the animal, holds in complete control all the ordinary chemical rules, which, but for it, would very soon destroy the fair proportions and beauteous appearances of this frail tenement of the soul, and resolve it into noisome, invisible gases, and dark and shapeless masses of earth.

And what is this vital principle, and where does it reside? are questions asked by every thinking mind. In an elementary work of this kind, it is not worth while to go into an extended notice of these topics; and this subject is only adverted to here as the most appropriate place to make a remark or two upon the once supposed connexion of the *life* of the animal with its *blood*.

"For the life of the flesh is in the blood,"* is a passage from Holy Writ very often quoted to prove that this fluid is the peculiar home of the vital principle. There are no doubt many, even at the present enlightened day, who, in their ignorance of the laws of physiology, and of the multiplicity of different parts requisite to constitute a perfect animal, remain contented with the view supposed to be unfolded to them by this solitary, unexplained text, and look no farther, believing they know all that can be taught them on the subject. Perhaps they become confirmed in these ideas on observing that an animal will quickly die merely by losing

* Leviticus xvii., 11.

a specific quantity of that precious fluid from a wounded bloodvessel, when they know, too, that in so short a time, no change in the solid structures of the body could have occurred adequate to such a result.

84. Life is not an accompaniment or an occupant of any one particular part or tissue alone, but every fibre and every drop of the system is in an appropriate degree endued with the principle. It is true, there are some parts which appear to be of no importance to the continuance of this incomprehensible gift, inasmuch as the body may be deprived of them, and no injury follow to its integrity; still, every part, however obscure or unimportant, while connected with the body, partakes of its vitality. If there is any one part which may be said to be pre-eminently the head and fountain of this principle, it is the *nervous system;* but it must not be forgotten that the functions of respiration, circulation, and secretion are, equally with the nervous system, necessary to the *immediate*, and that of digestion to the *remote*, continuance of life.

The scriptural text alluded to on the preceding page may doubtless, with implicit propriety, be construed as a precept uttered by the great lawgiver, to the effect that the life of every animal will be destroyed when he is deprived of his blood, and that the blood was the most convenient and proper to be offered upon the altar as a sacrifice. It cannot be understood to mean that the blood of an animal is the sole retainer of its life. That Moses entertained a more correct view of the subject, believing that life was a gift or principle *su-*

peradded to the organization of the animal, is clearly demonstrated by the seventh verse of the second chapter of Genesis: "And the Lord God formed man of the dust of the ground, and breathed into his nostrils the breath of life; and man became a living soul." The act of inspiring man with life is thus shown to be *subsequent* to his corporeal formation.

CHAPTER V.

MOTORY APPARATUS.

PART I.

85. The utility of all artificial machines depends upon *motion*, produced and modified in a variety of ways. The power which puts an engine or apparatus in motion is various in kind, and is derivable from many sources. In mills near water-courses, water is used as the moving power. In places where a stream of water is not accessible, this fluid, taken from wells or streams, may be converted into *steam*, which, in modern times, has become a very powerful agent. *Wind* is frequently employed to move machines. It is the means used to propel ships across the ocean, and, in defect of waterfalls, as the propelling force of mills for various purposes. One of these three is generally used where large and heavy machines

are to be moved, as they possess very great moving powers.

Sometimes motion is produced by letting a heavy weight fall slowly from a height, as in clockwork; sometimes by the elastic force of bent wood or metal, or of compressed air; and much more frequently than either is the power of brute animals and of men applied to similar purposes.

Recently a new motive power has been introduced, called electro-magnetism; it is an invisible agent generated by galvanic action. It appears to be of some promise, but is yet in the infancy of its application.

The chief sources of power, therefore, applicable to machinery, are the force of running water, of wind, of electricity, of falling bodies, of men and other animals, and of steam. They are called motive powers. Their subserviency to the wants of man is almost infinitely increased by the exercise of human skill, in the changes given at pleasure to their amount and direction.

But not a single instance can be named in which an engine of any kind is able to set itself or keep itself indefinitely in motion. No artificial machine has within itself the means of overcoming the resistance occasioned by the friction of its parts on each other, or, when once set in motion, of continuing in operation indefinitely. If it were otherwise, the invention of a "perpetual motion" might reasonably be looked for. A gristmill cannot turn without the aid of water; a steam engine without steam; a watch or clock without spring or weight, and so on.

If no artificial machine, then, can move its different parts upon each other without the assist-

ance of some motive power, how much less able must any engine be to move itself from one place to another. Suppose a cotton factory to stand on the banks of a river, and to be kept in motion by the water of the river running against its wheels; if the river should become dry, neither the factory nor its machinery could change its locality, and go over the country to another river to find a water-power. The engine of a steamboat or a railroad locomotive is put in motion by the steam generated in the boiler; but if the water or the fire fails, the engine and all attached to it must remain stationary until the power is renewed.

But the machine which we are now studying differs from all others in these two most essential particulars. It possesses within itself the power of moving its different parts upon each other, and also of moving bodily from one place to another. The latter is called the *power of locomotion*. Both these faculties are possessed by animal bodies, and by some of them in a very high degree.

To produce motion in the animal machine, one particular substance is employed, which is so placed and arranged as to perform very conveniently all the duties required of it. It is called MUSCLE.

86. Muscle constitutes all that part of the animal body which is known as flesh, as distinguished from fat, bone, sinew, or cartilage; it is the *red* or *lean* part of meat, and forms a very large portion of the bulk of the animal structure. In some animals it is white, as in the bodies of chickens and other birds, and in fishes.

The structure of muscle is very peculiar. When

seen upon the table after being cooked, it will be observed to be composed of a great number of small strings or fibres, lying very close to each other, and bound up together. These may be easily separated from each other, and it will be found that each one is like all the rest.

87. In the recently dead body, the muscular fibres are soft, flexible, and easily cut or torn asunder. They are then entirely devoid of any contractile power.

In the living body, on the contrary, they possess a high degree of contractility, i. e., they have the faculty of *contracting* or shortening themselves so as to bring the two ends nearer to each other, and this they can do with a great degree of force, and it is this force which constitutes, in fact, the power which all animals possess. In proportion to the contractile power of the muscles, is the individual said to be strong or weak.

The contraction alluded to is excited by a peculiar stimulus applied to the muscle by the nerves; and when the stimulus is removed or ceases to operate, the muscle relaxes and returns to its former length. These two properties are the distinguishing characteristics of muscular fibre.

88. The muscles generally lie just beneath the skin, and surround the bones, especially those of the extremities, which are completely enveloped by them. As they are found near the surface, they serve to give much of that graceful contour which the body and limbs exhibit, and in many instances their prominent outlines may be distinctly traced. The strong "cords," as they are often called, which are seen in the neck, one on each side,

running from behind the ear obliquely to the top of the breast-bone, are two muscles used for bending the head to one side or the other, according as either acts. The full, rounded protuberance seen on the front of the upper arm, between the shoulder and elbow, is a powerful muscle used to bend the elbow. The large swellings of the thigh and calf of the leg are formed chiefly of strong muscles, which are used mostly in walking, running, and similar exercises.

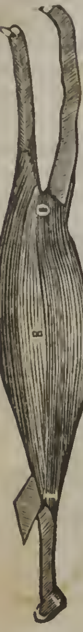
89. Each muscle is made up of a large number of fibres, bound up together in a thin, strong casing, called the "sheath." The fibres lie parallel to each other, and it is the contractions of the separate fibres, all acting at the same moment, that give to the muscle its great strength.

The muscles are all very distinct from each other, each one being enclosed in its own sheath, and easily separated from all other parts.

Each one is divided anatomically into three parts, viz., the *body*, which is the middle portion, full and round, and the *two ends*, which are smaller than the body; the latter gradually and gracefully taper to the extremities. Both ends are attached to some other body, and generally a bone. The fixed end is called the *origin*, and the moveable end the *insertion*, of the muscle. But a great variety is found in the forms of muscles, as represented in the cuts.

Figure 27 represents a form of muscle which, with slight variations, is one of the most common. B is the body of the muscle, O the origin, and I the insertion. The ends of the *drawing* are not the ends of the muscle, but are *tendons* attached

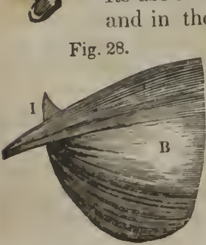
Fig. 27.



to the fleshy fibres, whose use will be explained hereafter.

Figure 28 represents an example of a muscle having a broad attachment at its origin O, and composed of a number of bundles or sets of fibres, running in different directions, but all terminating at one point, the insertion I. The fibres in each bundle run parallel with each other, but the bundles do not. They not only run towards one point at the insertion, but they are twisted a little upon each other, like the strands of a rope. By muscles of this shape a great variety of motions may be produced. If the bundles all act together, a straight movement will be given to the force; but if only one set contracts, an oblique direction will result; and a twisted motion also may occur. Such a form of muscle is found lying on the front of the chest. Its origin is at the ribs near the breast-bone, and its insertion is into the bone of the upper arm. Its use is to pull the arm *across the chest;* and in the direction in which the arm moves in the different stages of its progress during this action, it may be observed to have a rotary or twisted motion. This is given to it by the successive action of the different sets of fibres of this muscle.

Fig. 28.



90. Another form of muscle frequently found is that of the ring or circle. This is placed at the edges of the different orifices, as the mouth, the opening into and out of the stomach, &c. That which surrounds the mouth is just under the skin, and forms the outer part of the bulk of the lips. When it contracts it puckers up the mouth, as in

Fig. 29.

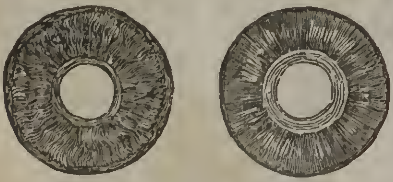
Muscles of the Face.

the act of whistling, and when the mouth opens wide, it is fully relaxed.

Another circular muscle is the one which surrounds the eye, fig. 29. This is situated just beneath the skin of the cheek and eyebrow, and when its fibres contract the eyelids are drawn very tightly together. The most beautiful and delicate of all is the muscle which forms the *Iris*, the dark, variegated part of the ball of the eye. This is a perfect ring, having a round hole in the centre, called the *pupil*, or commonly, the "apple of the eye." It is remarkable also for its extreme sensitiveness, as it instantly contracts when approached by a ray of light. The iris has two sets of muscular fibres, besides numerous bloodvessels and nerves. The first set of fibres converge from the outer circumference of the ring to the margin of the pupil, like radii, and hence are called the "radiated muscle." The second set is a ring of fibres, which forms the inner edge of the iris and

Fig. 30.

1 2



1. The Iris magnified, seen from the front, showing the radiated muscle.
2. The same from behind, showing the orbicular muscle.

the margin of the pupil. It is called the "orbicular muscle." When there is too great a quantity of light for the eye, the orbicular muscle contracts,

by which the pupil is nearly closed, and the light is partly excluded; but in shady or dark situations, the radiated muscle contracts and the other relaxes, by which the pupil is enlarged, and more light is admitted into the eye.

The action of this refined organ may be seen at any time in another's eye, by suddenly bringing a candle near it, when it will contract, and on removing it it will relax; or even by covering the eye with the hand, and suddenly removing it in a bright day, the same effect will be produced.

91. The corresponding organ in some of the inferior animals has a different shape. In the cat kind it is an oval, with the greatest diameter from top to bottom. The pupil being the opening through which light enters the eye, in this species that direction of the hole enables it more easily to look upward as its habits require; as in searching for prey in trees, &c. In grazing animals, as the horse and cow, the greater diameter is from side to side, as these require to embrace in their view as much as possible of a wide field. But man, requiring at times a view equally in every direction, has a perfectly round pupil.

92. Another form of muscle, and one which displays no less ingenuity than the others, is that of the *pulley*. Curious as it may seem, there are in the animal body several instances of this mechanical arrangement.

They are to be seen principally at several of the joints, especially those of the foot and hand. The muscles which bend the toes upward are placed on the front of, and are attached to, the bones of the leg. Long tendons are fastened to the lower ends of these muscles, commencing above the ankle, and

passing over the ankle joint to the top of the foot and toes. When the foot is stretched out far, the

Fig. 31.

View of the muscles which extend the toes and bend the foot. M, the common extensor muscle; T, the tendons of the same muscle inserted into the toes; L, ligament binding the tendons down.

muscles and tendons are nearly in a straight line with each other; but as soon as the foot is bent up a little, the tendons make a turn, as it were, around a pulley.

When the muscles act very powerfully, the tendons would be forced up from their places were they not bound down by strong ligaments running across them. These ligaments act like small cords, and are tenacious enough to keep down the tendons, however powerful may be the action of their muscles.

The same arrangement, though forming a more complete pulley, is found in the muscles and tendons which bend the fingers; but a description of these will be found in the chapter on the "Hand."

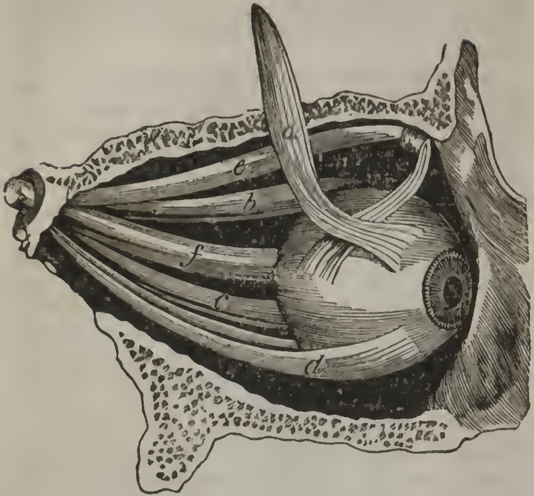
93. The most delicate and beautiful of all the instances of the pulley, to be found in the body, is one placed within the orbit of the eye.

Every observing person must be surprised at the great variety and number of the motions of the eyeball, although he may be unacquainted with its anatomy; but that surprise will be rather heightened than diminished when he becomes acquainted with the means by which it acquires such great facilities of movement.

The following figure presents a very clear view of the arrangement of the different little muscles, whose contractions communicate to the eye its motions upward or downward, to the right or left, or towards either of the four corners.

The muscles which move the eyeball are six in number, four of which are called "straight," and two "oblique muscles." Of the latter, one is the "great," and the other the "lesser oblique" (fig. 32).

Fig. 32.



Side view of the muscles of the eye in their natural position. *a b c d*, the four straight muscles (*a* is turned up to prevent the others from being hidden); *e*, the great oblique muscle; *f*, the optic nerve. (The second oblique muscle is not shown, but its situation may be inferred.)

The actions of the straight muscles may be understood from the figure; according as each contracts, the front of the eye is turned upward, downward, or to either side, in a perpendicular or horizontal line. Hence these muscles derive their appellation of "straight." But to produce the oblique motions of the eye is the office of the two oblique muscles.

94. The "great oblique," or pulley muscle, "is one of the most interesting in the body, and, as a marvellous work, offers a brilliant example of the mechanical wisdom of the Creator, demanding our closest attention." It arises from the margin of the aperture in the bottom of the orbit,* which transmits the optic nerve from the brain to the eye. Thence it runs forward, slantwise, to near the upper front edge of the orbit, where is fastened to the bone a cartilaginous ring, through which it passes like a rope over a pulley, and, turning backward, it increases a little in width, and is inserted into the back part of the ball of the eye. "When it acts, it rolls the eye about its axis towards the nose, and, at the same time, draws it forward and turns the pupil downward." The motions of the eye produced by this muscle are very extensive, and could not have been effected except by a muscle longer than could lie straight in the orbit, and hence we have a reason for the display of this beautiful mechanism.

95. Some muscles are found of great length; some very short, with very long tendons; some are broad and flat, some round, and some nearly square, and others hollow. But all are made of the same material, and their contractions and relaxations are produced in the same manner. *Every motion in the body*, however powerful, extensive, minute, or delicate, *is the result of muscular contraction.*

As the number and variety of the movements of the body are incalculable, the number of distinct

* The bony case or "socket" in which the ball and apparatus of the eye are securely placed.

muscles, it would be supposed, must be also great. There are in the body 436 muscles, all distinct and separate from each other; every one of which is capable of producing at least one motion, and various combinations of few or many of them may and do give rise to the infinity of movements from which the animal body derives its wonderful flexibility.

96. The study of the nature of the contractile power of muscles does not come within the scope of a work on the *mechanism* of the frame, but an outline of the subject, as far as we are acquainted with it, will not be inappropriate. The substance of a muscle has been stated to be divisible into smaller portions or filaments, called fibres. These fibres are as distinct from each other as are the bundles of them, or the muscles themselves. The fibres of some muscles are comparatively coarse, and others are very fine; but all, when minutely examined, are seen to be composed of an arrangement of "globules," united with each other, which bear a strong resemblance to the globules of the blood.

Each muscle is supplied with a nerve coming either from the brain or spinal marrow, and thus, of course, is connected with the mind, which inhabits the brain. Immediately after the nerve enters the muscle, it divides into innumerable ramifications, each of which goes to supply one of the millions of fibres composing the muscle.

The nerve is the medium of communication between the mind and the muscle, and through it is transmitted the stimulus of the will, which causes the muscle to act. For instance, when there is occasion to raise the arm, the desire or will arises in the mind, and is sent through the appropriate

nerve to the muscle which it supplies; the will thus sent is the peculiar stimulus which causes the muscle to contract. Each fibre contracts independently of all the others; but as they are all supplied with the stimulus at the same instant, each one being furnished with a filament of the same nerve, they all contract simultaneously; and although one fibre has but a trifling amount of power, the aggregate of the whole produces the immense strength which some muscles are known to possess.

The nature of the stimulus which is given to the muscles by the nerves never has been, and probably never will be, ascertained.

97. The muscles of the system are divided into two large classes, distinguished by the one being entirely under the control of the will, hence called *Voluntary*, and the other equally beyond its control, and called *Involuntary*. The former we may move or not, as we please; among them are the muscles of locomotion, of the voice, of the eyes, &c., while the latter class comprises the muscles of circulation, as the heart and bloodvessels, those of digestion, and a few others. The muscles of respiration belong exclusively to neither class; for they are so far voluntary, that their action may be suspended by the will for a *short time*, but it is impossible for a person altogether to stop their action, otherwise suicide might be committed merely by restraining respiration, in other words, producing suffocation. They are, therefore, to be considered as both voluntary and involuntary; the former in a much less degree than the latter. The surpassing wisdom of this distinction between or-

gans whose minute structure exhibits not the slightest trace of difference, is clearly apparent. The involuntary muscles are those which are intimately concerned in the continuance of life; and if they had been, like those of the hand or the foot, placed under the guidance and care of the wayward minds of their owners, how soon, amid the engrossing occupations of time, or from the wicked determination of the self-destroyer, would their actions be deranged, forgotten, or neglected, and life on the instant be forfeited.

98. Not the least astonishing among the faculties of the muscular structure is the velocity of movement of which it is capable. A striking exemplification of this may be seen in the rapid action of the muscles of the fingers in playing upon musical instruments. But a more remarkable example are "the muscles connected with the organs of speech, where, in rapid enunciation, the number of distinct contractions that take place in order to form certain combinations of vocal sounds is very great, each word, or, rather, each syllable, requiring several contractions, which must succeed each other in rapid succession, with proper intervals between them." In the action of the fingers in the former instance, the contractions are generally greater in extent, and, therefore, must proceed with proportionably greater velocity, although they do not succeed each other so rapidly as those of the vocal organs.

TENDONS.

99. The substance of muscular structure, when closely examined after death, is found to be soft, possessed of very little tenacity, or easily torn in pieces. So very delicate is its texture, that a muscle which, in the living body, would be able to sustain a weight of 100 pounds by its contractile power, would be unable, when deprived of life, to hold a weight of ten pounds. That is, if it were separated from the body, and it should be held in the hand by one end, and ten pounds were attached to the other, the muscle would break in two. From the invisible and incomprehensible principle of life, a substance derives an almost incalculable power, of which in a few moments it may be deprived and be rendered as powerless as an equal bulk of untwisted flax, and yet not a vestige of alteration, chemical or mechanical, is perceptible in its structure. But, tenacious as its fibres may be during life, there is a limit of power beyond which it would be unsafe to try it. There are some situations, however, in which it would be hazardous to exert a moiety of a muscle's strength, were it unfurnished with efficient protection. Such a situation is that where a strong muscle is attached to a bone. Bone is a material very different from muscle in its structure, and is the same in properties before or after death. It is hard, firm, strong, and inflexible, and somewhat brittle, and possesses none of the softness and delicacy of muscle. A bone, therefore, will endure the application of a much greater force than muscle without injury.

100. When a muscle contracts, its ends are approximated, and, of course, one of them at least must be moveable; therefore, whatever substance is attached to the moveable end, must move with it when the muscle acts. The substance upon which the muscle exerts its power is generally a bone, and the motion is brought about through the intervention of a joint.

But it is very rarely that a muscle is found fastened directly to the substance of a bone; the organs in many instances are required to exert such great strength, that the strongest attachment possible between the two would be too feeble, in consequence of the softness of the muscle, and a separation would be the result. For example, let us take the muscles of the calf of the leg and the heel-bone. These muscles are used in walking, running, leaping, and such exercises, and being connected with that bone, when they contract they raise the heel and throw the whole body forward. When, as we often see, a weight of one or two hundred pounds, carried on the head or in the hands, is added to the weight of the body, these muscles have to exert extraordinary power, and the slender connexion which only could be made directly between their structure and the bone would be insufficient to sustain it; a painful and inconvenient separation would ensue, requiring weeks of cautious repose for the reparation of the injury.

Most happily, in every requisite situation, the animal frame is provided with a preventive against such a distressing event. This is the intervention of a third substance between the bone and muscle,

which possesses properties most admirably adapted to its offices. It is called *Tendon*, and goes commonly by the name of sinew.

101. Tendon is a very peculiar substance, unlike any other in the body. In texture it more nearly resembles cartilage, but possesses no elasticity. In strength it is scarcely inferior to bone, yet it is perfectly flexible; it is much denser and firmer than muscle, but is totally void of contractility, and is insensible, having no nerves. It is generally found in the form of long, slender strings, but frequently is observed in broad sheets,* and short and thick cords. It does not appear to lose any of its tenacity when deprived of life; and on account of its immense strength and great length in some inferior animals, it is often used by Indians for the manufacture of bowstrings and for other purposes, for which it is well adapted also by its smooth and glossy surface.

102. The longest tendons in the human body are in the hand and foot. The muscles which bend the fingers are placed on the arm between the elbow and wrist; they do not go beyond the wrist joint, and their power is exerted upon the fingers by means of slender and strong tendons, which pass over the joint (confined down by a ligamentous band lying across them) and through the palm to the different joints of the fingers. All the immense force which is often exerted by the hand in grasping and pulling, must, of course, be borne by these fine cords; but I know of no instance in which they have ever given way. The

* In this form it is called, in some parts of the country, by the singular name of *Packwax*.

muscle or the bone is more likely to yield. On the back of the hand, the tendons which assist to extend the fingers may be distinctly traced, one going to each finger and thumb.

The most delicate tendons are to be found attached to the minute muscles of the eye and heart. They there appear like slender threads of glossy white silk (figs. 3 and 4).

103. The flexibility and tenacity of tendon are the two qualities which render it appropriate as the medium of union between a muscle and a bone. At its muscular end its fibres are closely and strongly interwoven with those of the muscle, in such a manner that it is next to impossible to separate them clearly, even with a knife. They so gradually slide into, and become incorporated with, each other, that it is difficult to tell where one begins and the other ends. The same remarks are applicable to the end which is attached to the bone. Numerous filaments of the tendon glide in between the laminæ of bone, round which they intimately entwine themselves; and so firm is the union, that an effort to separate them results in a rupture of the tendon or bone before the connexion can be severed.

104. Another very important advantage derived from the use of tendon is, that much space is saved and a graceful form given to the structure of the limbs. Let us compare, for instance, the shape of the leg as it is, with what it would be, deprived of its tendons. We find the great muscles which form the calf tapering gradually from their thickest part down to a much smaller compass, and terminating in a strong tendon, which unites it to

the heel, and through which it transmits its power. By thus concentrating the contractile force of the muscle, not only is there a diminution in the quantity of matter in the soft parts without loss of power, but the smaller tendon requires far less surface of bone for its attachment, thus also lessening the size of the heel and reducing the weight of the body.

Suppose, now, the muscle, instead of diminishing, had continued down to the heel of as large size as at the calf; not only would the ankle have presented awkward and inconvenient dimensions and form, but the heel-bone must have been made five or six times its present size to have presented sufficient surface for the attachment of the muscle. A more striking exemplification still may be seen in the muscles and tendons of the hand. Suppose, instead of the graceful tendons, the *muscles* of the arm had continued their course over the wrist, and with undiminished bulk had been attached to the fingers; not merely would we have been deprived of the aid which their present shape affords us in innumerable delicate manipulations, but in many of the powerful operations to which they are now safely adapted, the muscles would have been liable to numerous painful disorders, from which the insensible tendons are totally exempt. We find, therefore, not only symmetry and convenience of form and facility of motion with concentration of strength, but also a great diminution of the weight of the whole body, derived from the present arrangement, all of which would be lost in the reverse condition.

THE LEVERS.

105. As complete as any of the mechanical contrivances of the body are the Levers. In the science of mechanics, levers are divided into three kinds, depending upon the relative situation of their three points, viz., the power, the weight, and the fulcrum. The instrument, in its plainest form, is merely a straight, stiff bar; and its power, which, under the most favourable circumstances, is very great, depends upon the relative distances of these three points from each other.

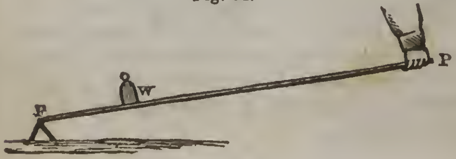
106. The *first kind* of lever is that in which the power is at one end, the weight to be raised at the other end, and the fulcrum, or point on which the lever rests, is somewhere between the two.

Fig. 33.

The common crowbar and the handle of a pump are instances.

107. In the *second kind* of lever, the power is

Fig. 34.



at one end, the fulcrum at the other, and the weight between the two.

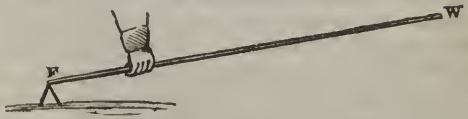
The wheelbarrow and nut-crackers are instances of the second kind.

The difference between the first and second kinds is merely that the fulcrum and weight have changed places.

The lever has two arms, each commencing at an end of the lever and extending to the intermediate point; and the power derivable from the use of either of these kinds depends entirely upon the disproportion in the lengths of the two arms. That is, if the long arm is ten times the length of the short arm, a power equal to one pound will be equal to a weight of ten pounds; if the long arm is twenty times longer than the short arm, a power of one pound will balance a weight of twenty pounds.

108. The *third kind* of lever has still a different arrangement of the three points. The weight is at one end, the fulcrum is at the other, and the power is placed between the two.

Fig. 35.



In this kind of lever there is not only no gain of power, but there is a great loss of it; there is, however, a great advantage derived from its use, viz., the gain of *velocity* in the movement of the weight. A ladder, while being raised against a house, constitutes a lever of the third kind. The

foot of the ladder is the fulcrum, the power is applied near the foot, and the ladder is itself the weight.

109. The lever is among the most powerful of mechanical instruments, and its three varieties of form render it applicable to a great many purposes wherein great force or great velocity is required, while its unequalled simplicity of construction recommends it in almost every situation. In every artificial machine, a great aim of the inventor is to bring in the aid of the lever whenever he can, as from it he can generally derive a greater power in a smaller compass and with less cost than from any other of the mechanical contrivances.

In the construction of a machine so complex, and uniting in one whole so great a number and variety of separate parts as does the animal body, it may readily be believed that its Omniscient architect, though possessing unlimited means, would not be less wise than man, and fail to employ those measures which would accomplish his ends in the most simple, most economical, and most powerful manner. If we trace the impress of his divine mind through the universe, we are everywhere surprised not less at the immensity and power of his operations than at their simplicity. The union of strength and simplicity is nowhere more strikingly exemplified than in the erection of this mortal habitation of our souls, "the house we live in."

Conclusive evidence of this is found in the application of the lever to every part of the bony structure where it can possibly be applied with

advantage, and, moreover, in the selection of that *kind* of lever for each particular position in which it is evident it should have been preferred before the others.

110. We have in the body several instances of each of the three kinds of lever.

Of the first kind, an example is presented in the forward and backward motions of the head. The scull, in the erect posture, rests upon the upper bone of the spine, and is thrown backward or forward by appropriate muscles placed at the back of the head and neck, or at the front under the chin. If an imaginary line is drawn along the base of the scull from the chin to the back of the head, it will represent the lever. The spine on which it rests is the *fulcrum*, the *power* (the muscles) is placed at one end or the other, as the head may be moved one way or the other, while the *weight* is the head itself.

111. *Of the second kind*, a striking instance is seen in the foot as it is used in walking. The

Fig. 36.

lever is the foot itself, from the heel to the toe; very irregular and uneven in its form, yet, to all intents and purposes, acting in the exercise mentioned precisely as a second kind of lever.

In figure 36 we have a view of this arrangement. P is the point where the muscle, M, of the calf of the leg is attached by its tendon, and where it applies its *power*. F is the *fulcrum*, the point on which the foot rests when the heel is raised; and W is the *weight*, which in this case is the whole body supported by the leg.

It will be perceived, that in this arrangement the weight is nearer the power than the fulcrum; in other words, what is generally the long arm of the lever is here made the shorter arm, and what is usually the short arm is here made the longer. The inference to be deduced from this fact is, and very properly, that there is a considerable loss of power; for it will be seen, by a glance at the figure, that if the weight had been placed nearer the fulcrum, less power would have been required in the muscle to raise the heel. A muscle of less size would have been sufficient to perform that duty, or, what is equivalent, the same muscle could have done more work. But we may also see that the power which appears to be lost is only sacrificed for the attainment of an equally important end, that is, velocity. Had the leg been united to the foot at a point nearer the fulcrum, it would have required a much *longer contraction* in the muscle to raise the leg through the same distance, which would have made necessary a *much longer muscle*, and caused a loss of time in the contraction which would very poorly have compensated

for the economy of muscular strength. Besides, the present symmetry of the limb would have been lost, and the necessary exercise of running greatly impeded. What, therefore, is lost in power, is gained in velocity.

112. *Of the third kind* we find several remarkable and beautiful examples.

The instance generally adduced is one which, in a striking degree, illustrates all the losses and all the gains in the employment of this mechanical power. This is the "forearm," the part below the elbow. The muscle which bends the elbow-joint and raises the hand towards the head, lies in front of the upper arm, and forms, when the arm is bent, the large fleshy ball, apparent in all individuals, just above the elbow. The origin (O, fig. 37) of this

Fig. 37.

muscle is by two heads (hence called the *biceps*), formed of long tendons, T (fig. 27 is a representation of it), which are fastened to the bones of the shoulder. Its *insertion*, I, is also by a strong tendon into the large bone of the forearm, *near the elbow*-

joint. It of course has to pass over the front of the joint.

The arm and hand here constitute the lever. E is the *fulcrum* at the elbow-joint. B is the body of the biceps muscle, attached by a strong tendon at I, and forming the *power*, while the *weight*, W, is the hand and its contents. When the muscle contracts, the lower end must move and take the bone with it. The bone of the upper arm being fixed, those of the lower arm turn upon it at the joint, and the hand is raised in a curved line.

113. A more disadvantageous arrangement as regards the amount of power necessary could not have been contrived. For when the arm is fully extended, at the first contraction of the muscle its power is exerted in nearly a direct line with the bones, and almost all its force is employed to overcome the obstacle presented by their position; the nearer a right angle, the more advantageously does the muscle act upon the bones, and vice versa. But in the most favourable position there is a great loss of power. To repeat, however, what has been before said, in other terms, "we shall find it to be a general fact, or, as it is termed, a law of the animal economy, that muscular power is always sacrificed to convenience. Had the object been to raise the weight with the least possible power, the muscle would have been placed on the forearm, and the tendon inserted into the lower part of the shoulder-bone; but in this case the awkwardness of the limb would have much more than counterbalanced the supposed advantage of the saving of muscular power. The remark applies with still greater force to the fingers. Had the present or-

der of muscles and tendons there found been reversed, and the flesh of the muscle been placed on the fingers, the hand would have been almost useless from its clumsy form."

114. Another important acquisition in this distribution of the points of the lever is the great velocity.

By referring to figure 37, it will be made evident that the hand will move through a far greater space than the end of the muscle in the same time. In carrying the hand from the most extended position to the shoulder, a distance of at least three feet in an adult, the muscle is not shortened more than two or three inches. *Rapidity of movement* is one of the most valuable aids we possess in common with most other animals, and we acquire it in this perfect manner. Paley judiciously remarks, "that there are many more cases in which it is useful to raise a small weight rapidly than a large one slowly."

115. Another instance of a lever of the third kind is the leg. The muscle which throws the leg and foot forward lies in front of the thigh, and in size is commensurate with the great power required of it. But in its attachment it presents an interesting exception to the general mode. In the place of having a long tendon to go over the knee-joint to be fastened to the upper end of the leg, we find at the front of the knee a round, rather flat, and moveable bone, called the "knee-pan" or patella, which is plainly discernible. This bone serves a double purpose. The knee-joint, from its size and position, is more liable to injury than almost any other; and following the universal rule of

an all-wise Creator, that the most protection is extended to the part most exposed to accident, this bone is placed as a strong shield, directly in front of this very important point, to secure it against the action of injurious agents; an end attained far more effectually than if its place had been supplied merely by the tendon of the muscle. But it offers no impediment to the action of the muscle; on the contrary, its position and mobility greatly assist it. The tendon of the muscle is attached to its upper edge, while another tendon unites its lower edge with the bone of the leg. When the power of the muscle is exerted, it is transmitted through this bone more efficiently than could have been done with a long tendon running over the joint.

116. "Amid so many examples, where muscular power is expended for the purpose of producing some important benefit to the system, there are a few instances of a contrary kind, where the parts are evidently formed to *assist* muscular action. The heads of the bones into which the tendons are inserted not unfrequently swell out into rounded projections, by which means the muscles act upon the bones at a less acute angle." An example of this is the heel, which projects far back beyond the line of the leg, to give a better opportunity to the muscles to be attached and to act. (See fig. 36.) Another striking example is in the elbow (fig. 38).

The point on which the elbow rests when we lean on the table is a projection of one of the bones of the lower arm. To this is attached the tendon of a large muscle, which lies on the back of the upper arm, and whose office is to *extend* the arm. It can do this with great force, in which it

is materially assisted by this projection, as it enables the muscle to act upon the bone more at

Fig. 38.

a right angle, which is the most favourable position. This presents us, also, with another good instance of the chief advantage of the third kind of lever, *quickness* of movement in extending the arm, as in throwing a stone.

The general principle, however, which has been alluded to, still holds good, "that the quantity of power employed appears to have been no object in the construction of the body, but that it is always sacrificed, without any reserve, either to general convenience, to symmetry of form, to the gaining of velocity, or to the saving of the extent of contraction." The few instances to the contrary which might be adduced, can only be regarded as exceptions to the general rule ; exceptions founded in the same surpassing wisdom that has erected the principle.

CHAPTER VI.

MOTORY APPARATUS.

PART II.

THE BONES AND JOINTS.

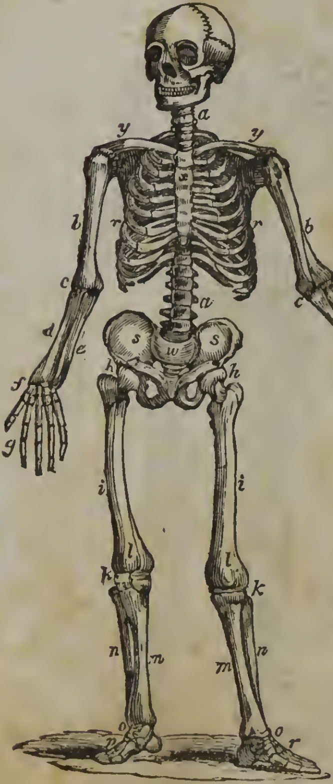
117. THE muscles, the organs *by* which motion is produced, having been considered, the next subject to be studied is the means *through* which the former are enabled to operate, and the parts which are moved by them. These are the *Bones* and the *Joints*.

In this study we shall find instances no less numerous than in other structures of the body, in which our attention will be arrested by the display of surpassing ingenuity evinced in the construction of a framework in every respect surprisingly efficient.

The anatomical divisions of the skeleton are three, viz., the *Head*, *Trunk*, and *Extremities*. The first is well known; the second embraces all the parts *immediately attached to the spine*, except the head; and the third comprises the shoulders, arms, and legs, or the *upper and lower extremities*. The trunk (fig. 39) consists of the *spine*, *a a;* the *ribs*, *r r;* the *sternum*, or breast-bone, *x x;* and the *pelvis*, *s s;* *w*, the middle bone of the pelvis, called *sacrum;* this supports the spine; *y*, the collar-bone; *b*, the *humerus;* *c*, the elbow-joint; *d*, the *radius;* *e*, the *ulna;* *f*, the *wrist;* *g*, the *phalanges* of the fingers; *h*, the hip-joint; *i*, the *femur;* *l*, the *patella*, or knee-pan; *k*, the knee-joint; *m*, the *tibia;*

n, the *fibula*; *o*, the ankle; *p*, the *phalanges* of the toes.

Fig. 39.



Front view of the Skeleton.

Fig. 40.

Rear view of the Skeleton.

The shaded outline (fig. 40) represents very accurately the fleshy bulk of the body, and the position of the bones within.

118. In looking at the skeleton (which is the framework of the body, upon and around which all the other parts are built), it seems as if every quality of matter, which could possibly be usefully employed, had been brought together and blended with each other in the most harmonious proportions, so as to produce a structure capable of sustaining, in the most perfect manner, all the various uses to which it is put, and of successfully resisting the innumerable destructive influences to which it is continually subjected. We find *hardness* combined with *toughness; strength and firmness* with a great degree of *compactness;* and an admirable arrangement, by which the sizes of individual bones, or of parts of a bone, are *increased in bulk* when required, without any addition to their *weight* or diminution of their strength.

119. The substance of bone is the hardest of all the materials composing the body. Its chemical composition displays a blending together of two totally different materials, unlike in both their physical and chemical properties; the one being hard and *brittle*, while the other is *soft, tough*, and very *flexible;* neither of which qualities, independently, does a healthy bone possess. By the union of these abstract properties in proper proportions, however, there results a condition of stiffness and toughness, without flexibility, peculiar to bone, giving it its high value. It will be manifest, on the least reflection, that *flexibility* would be totally improper in bone, having to bear, as it does, the en-

tire weight of the body, and forming all the joints. And yet we find this property of matter very conspicuous in one of the two constituents of bone when separated from the other; it becomes neutralized by the combination of the two, and forms, with the brittleness of the other part, the hardness and strength so remarkable in bone.

120. The two constituents of bone alluded to are the *animal portion*, and the *earthy* or *mineral portion*. The former is the tough, flexible part, and the latter the brittle part. The two are very easily obtained separately.

The animal portion may be obtained by putting a clean bone of any animal in a vessel of dilute muriatic acid. In a few hours, on removing it from the acid and washing it carefully with water, it will be found to have lost its characteristics of bone, to be soft and of a yellowish colour, but yet to retain with perfect exactness the shape and size of the original bone. It may be tied in a knot (if a long bone) without breaking, to exemplify its toughness and flexibility.

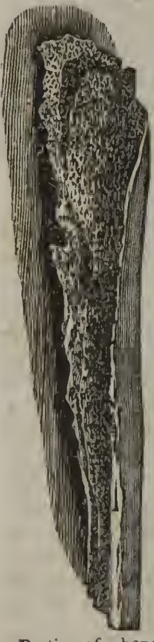
Fig. 41.

Bone in a knot.

The action of the acid has been to dissolve the earthy portion, for which it has a strong affinity, and separate it from the animal portion, which it has no power to affect.

121. The earthy portion is obtained by putting a sound bone into a charcoal or anthracite fire; the great heat consumes the animal substance of the bone, and dissipates it entirely in vapour; but it has no material effect upon the mineral part, which may be taken from the fire when the smoke and vapour have ceased to be given off.

Fig. 42.



Portion of a bone calcined.

This part will be found to be white, and also to be of the same form and size as the original bone. It is then so brittle and tender that pieces may be taken out with the finger nail, and it may be crumbled between the fingers.

It has been said that each of these portions, when separated from the other, retains the precise form and bulk of the bone from which it is derived. This will convey to the observer substantial proof of the extent to which the union of the two is carried in the formation of the complete bone. Every particle of each bone contains its due proportion of each constituent, so that the whole bone is alike firm and strong in every part.

122. But it is well known that the proportions of these two parts are not always the proper ones. In some individuals, the bones possess a larger share of the earthy matter, and in some there is too great a quantity of the animal matter. A preponderance of the former gives to the bones too much brittleness, and renders them very liable to be fractured, while, with a superabundance of animal or deficiency of earthy substance, the bones become too flexible, and yield under the weight imposed upon them, producing crooked and deformed limbs or bodies.

Both these conditions are produced by disease, when they are found in middle-aged adults.

123. There are, nevertheless, variations in the proportions of these two parts almost continually occurring in every healthy individual, which are widely different in their extremes, and given to us by an inscrutable superintending power for the most beneficent purposes. The variations are found at the different ages of the individual.

In infancy the bones possess a much larger proportion of animal than of mineral substance; in fact, when the foundation of a bone is first laid, it contains almost no earthy matter at all, being composed almost wholly of what very closely resembles *cartilage*. The bones in infancy are, therefore, not stiff and hard, as in after life, but are considerably yielding and flexible. But as the child grows, the bones become gradually more solid and firm, and more capable of supporting its body and of sustaining the action of its muscles.

This is a beautiful provision for protecting the infant against the consequences of its own helpless-

ness. It would be useless to give perfect bones to a child that has not muscular strength enough to support its own body, as it could have no employment for them; and in its early attempts to walk, every time that it should fall upon the floor or against a table, they would be in danger of fracture; or even when still younger, it should accidentally fall from a bed or the nurse's arms, broken bones would be its continual misfortune. Such unnecessary perfection of structure, therefore, is not found in Nature's wise code of laws. As it now is, a young child may meet with such accidents every hour in the day; it even may fall upon its head, and receive no permanent injury. The bones, being composed chiefly of animal substance, *bend* before the blow, without breaking, and by their elasticity immediately recover their proper position and form.

On account of this disproportion of the two constituents of bone in infancy, caution is always necessary, in rearing young children, to avoid too early a pressure upon any of their bones, particularly those of the lower extremities. From the readiness with which the bones will bend under pressure, the weight of the child's body is sufficient to produce a permanent alteration in its shape.

For the same reason, the habit which some mothers and nurses have of carrying the infant always upon the same arm, or laying it in one position, should be carefully guarded against; many a spine has doubtless been crooked for life by that reprehensible practice, and I know at least one instance in which a striking and ugly alteration in the form of the scull has been caused in the same way.

One side is flattened considerably by its constant pressure against the mother's arm when young and soft.*

124. The bones do not become entirely solid, that is, every part of the bone does not receive the exact proportions to form the strongest material, until the age of puberty. They retain a certain degree of their flexibility and softness, but which gradually diminish until the strength of the muscles requires a firmer substance for attachment, and they then receive the proportions necessary to constitute levers of the most firm, durable, and unyielding character. They are then able to endure all the force which can be put upon them by the individual, and it is only when an extraordinarily severe blow is given them from without that they will break.

125. In old age we find another and a very different change in the composition of bone. Instead of either the yielding structure of the youth, or the firm, unyielding material of vigorous manhood, we have, in going down the vale of years, a skeleton

* Doubtless many other instances of like character might readily be found; and it is a matter of authentic history, that some of the American Indians are in the practice of altering the shape of their heads, to suit their ideas of beauty. They accomplish it by compressing the children's sculls when imperfectly developed, by applying flat pieces of wood against them, and confining them in their places by tight bandages. The fashionable shape is now said to be that of a quadrangular cone. The form of the brain must of course be altered to correspond with that of the scull. It is in this manner, also, that the Chinese produce such horrible deformities of the feet of their females. These practices appear to us as not only absurd and ridiculous, but as wickedly tampering with the order of "Heaven's first law," and yet are neither of them more obnoxious to these imputations than the present *civilized* practice of compressing the chest.

which has lost much of its firmness and strength, and which, in the place of *toughness*, has assumed a *brittle* character; a condition the very reverse of that of childhood.

The bones become strikingly deficient in the animal matter, giving a preponderance to the mineral substance, a change which arises from the general decay of the system. The earthy part of bones, being the more durable and less liable to decay, is more permanent, and partakes less in the changes of adult life than the animal portion; and hence, when old age creeps on, it is less influenced by the absorbent system; the animal part is more readily removed, and, from the inactivity of the circulation, is not proportionately restored. Hence the deficiency of this part of the bony structure. There is, fortunately for the aged, a corresponding deficiency of muscular energy, otherwise their bones would be unable to bear the force which might be exerted upon them, and, from their fragility, would be too readily broken; and it is known by every surgeon, that an old bone, when broken, is far more difficult to mend than a young one. The proper ratio in the diminution of the firmness of the bone and the strength of the muscle does not, however, always exist; the bones sometimes grow very brittle, while the muscles continue strong, and accidents may happen to a bone by too great an exertion of the muscular strength. A well-authenticated case is on record of an old gentleman who, from this disproportion of strength between his muscles and bones, actually broke his arm in the act of pulling on his glove.

126. On the other hand, cases are sometimes

met with in middle age, in whose osseous system there is not a due proportion of the earthy constituent. While the muscular system has arrived at its condition of maturity, and requires for its free and complete action a strong and firm bony structure to operate upon, the latter does not correspond in hardness, but, in consequence of this deficiency, fails to present a proper resistance to the power of the muscle, and bends before the force applied to it. This unnatural condition is owing to the want of a proper balance in the vital actions of the system; the digestion of the food, the circulation of the blood, and the absorption of the decayed material of the body, do not go on in their proper relative ratio.

Such unfortunate persons are readily known by the great degree of deformity of their limbs, and by the facility with which they become distorted without fracture.

To so great an extent does this diseased condition occasionally exist, that some long bones may be bent entirely double, or curved into a circular form.

"On dissection of those who have died, all the bones, except the teeth, have been found unusually soft, so that scarcely any of them could resist the knife, and the bones have been found to contain a great quantity of oily matter and little earth."

Fortunately for mankind, it is a rare disease.

SHAPE OF BONES.

127. In examining the mechanical structure and arrangement of the different parts of the skeleton, we may observe a very great variety in the shapes of the bones; and every one must be struck with the perfect adaptation of each bone to its situation and its uses. Thus we find in the arm, and thigh, and leg, *long* bones of cylindrical form, with their ends enlarged to form strong joints. The ribs are also long bones, but they are very much curved and twisted. Then we find some bones very broad, flat, and thin, such as the bones of the scull, the shoulder blades, and the hip bones. Again, some are thick and square, or cubical, as those of the ankle, which has seven, and the wrist, which has eight bones. Others are found of which no word will express their shape, being so exceedingly irregular or crooked; such are the *vertebræ*, or bones of the spine, and some of the bones of the face. These have a great many projections standing out from them, to furnish more room for the attachment of muscles. The long ridge of bones which may be felt in the back, extending downward from the head, is composed of long projections from the bodies of the vertebræ. These projections are called the *Spinous Processes*.

Each of these forms of bone has its peculiar advantages, and it will be found, on inspection, that the integral construction of each bone very greatly assists its general shape, in its applicability to its particular purpose in the skeleton. A few of these will be enumerated.

128. 1st, The long bones. When one of these is sawn in two across the middle, it will be found to have a hole running longitudinally through it, the diameter of which is nearly one half of the whole diameter of the bone.

Fig. 43.

Section of a Thigh Bone, showing the canal, C, running through it.

This canal, during life, contains a semifluid substance called *marrow*, which has a double purpose; it serves as a bed in which are placed the principal bloodvessels of the bone for their better protection, and it answers for nutriment to supply the whole body when disease or privation overtakes it. There is here a reservoir of food always at hand, which, in time of health, is kept full, and readily accessible when required to supply deficiencies from the usual sources.

This cavity in the bone serves also an important mechanical purpose. By taking from the bone so much of its solid structure, it renders it also much less heavy, but without depriving it of any of its strength. On the contrary, it is supposed that this cavity has the effect of increasing the firmness of the bone. The long bones being all levers, and having to bear the greatest burdens of the body, the strongest form, as well as the firmest material, must be employed. No form combining strength with lightness can be found

more capable of sustaining a great strain or a heavy weight than that of the arch, and in the hollow cylindrical bone we have a *double* arch. A great point to be attained in the construction of such a bone is to arrange the least possible quantity of matter in the most advantageous manner.

To prove the superiority of this form, take half a sheet of letter paper, and roll it into a cylinder or tube about half an inch in diameter. If this tube is held firmly in the hand by one end, a considerable weight may be suspended upon the other end, by a string passing over it, without its bending. If, then, the paper be flattened down so as entirely to destroy its arched or tubular form, it will not support by far so heavy a weight as before, although the quantity of material is precisely the same. The *form alone* gives it greater strength. This simple but beautiful mechanism is applied with all its advantages to all the long bones of the body.

129. 2d, The flat bones. These bones, occupying very different situations in the skeleton, are variously constructed. The shoulder blades (which form the tops of the shoulders, and are plainly to be seen and felt on the back, each side of the spine), for their apparent size, are the lightest bones in the body. The principal part of them is devoted simply to the attachment of various muscles, without any particular requisition for strength, except at the upper end, where it forms a part of the shoulder joint, and is very strong. They have so little substance in the broadest part of them as to be diaphanous.

The hip bones. These are much thicker than

the last mentioned bones. When they are in their proper places in the skeleton, they form the basis on which the spinal column rests; and they, in turn, are supported by the lower extremities, as in them are the sockets of the hip joints. In their natural positions they are so situated with regard to each other, as, together with the last bone of the spine, to form a kind of basin; hence this part of the skeleton is called *Pelvis*.* By referring to the front view of the skeleton, it will be seen that this basin is placed, as it were, nearly on its edge, so that the rim or edge of the circle is presented nearly in a full view. By this arrangement, this ring of bones is made to act in a double capacity. 1st, As a *basin* to support the bowels, stomach, and all the abdominal viscera; and, 2d, As a *double arch*, resting upon the thigh bones, and sustaining the spine and all attached to it.

On examining these bones, they will be found to have several vacancies at different parts; for instance, in the lower front part is a large oval-shaped hole, and in several parts of the two edges are deep notches; all of these, particularly the hole in the body of the bone, serve the very important purpose of diminishing the weight, which they do without lessening the strength of the part, but rather increasing it, at the same time giving more points for the adhesion of muscles.

The other flat bones, viz., those of the head, present some very interesting and peculiar points, which will be noticed in another place.

130. 3d, The cubical and irregular bones are

* A Latin word, signifying a sort of vessel which was used in washing the feet.

only remarkable as presenting a great variety of shapes, each being somewhat different from all the others, and curiously adapted to its place and uses.

They will all be more particularly described under other heads.

THE JOINTS.

131. The means through which the muscles are enabled to act upon the skeleton, viz., the Joints, next claim our attention.

Whenever a motion is made between two bones, however slight it may be, there is to be seen there an apparatus for facilitating the action. There is a certain arrangement of appropriate materials in the construction of the joints, contrived with great ingenuity, evincing a foreknowledge, an adaptation of means to ends, which precludes all possibility of admission to the thought that the animal machine merely *happened* in its present state of perfection; a construction which is in itself an argument alone sufficient to prove a Maker. In the construction of an engine of any kind, the mechanic, in making its moveable joints, aims at three principal points; viz., *strength* in the formation, *durability* in the materials, and *freedom from friction* in the working. The first point he gains by using some particular arrangement best adapted to the form of joint required; to procure a durable joint, one which will bear a great deal of working without wearing out, he generally constructs it of material much harder than the other parts of the machine. Thus, in a steam-engine, the parts which move upon each other are generally faced with steel; and in a

watch, very often, the pivots are made to run in sockets formed of precious stones, which are very hard. To diminish friction in large machines, common oil is used to lubricate the joints and cause the parts to pass smoothly over each other; but in more delicate constructions, as a watch, great pains must be taken to procure some lubricating material which will not become stiff and dry, otherwise, instead of assisting, it would interfere with and clog the movements of the apparatus.

Such a substance is a great desideratum, and, until lately, nothing has been known to answer all the required ends.

Nevertheless, with all the ability of human intellect, no machine has ever yet been made which would not wear out in some of its parts in a comparatively short period; either the material would give way, the moving power would be exhausted, the joints become stiff and immoveable, or the parts rubbing upon each other become worn off and require renewal; or the lubricating fluid would become deteriorated, or its supply cut off, and the machine be obliged to stop for want of it. Neither, it may be said, was there ever an artificial machine in which the mechanic has not observed some defect which he might have avoided could he have foreseen it, or some part wherein an improved form is admissible.

If, then, man, with the wisdom of ages and all his boasted ingenuity, cannot produce a machine without such striking defects, and if we can point to a machine entirely free from all these objections and deficiencies, which can supply all its own wants; one which we know man cannot make, and

of which the first was as perfect as the last one made, shall it be said that that machine was made by *chance?* that no *thought* was used in its construction? To the mechanism of the joints of the animal body we can point in full confidence of their sufficiency to establish incontrovertible proof of the existence of an Architect infinitely surpassing man in ingenuity of design and power of execution.

132. A joint is the union of two bones with each other, and may be either *moveable* or *immoveable.* The latter kind are few in number, and will be noticed in another place. Of the moveable joints there are several varieties, as,

1st, The ball and socket joint.

2d, The hinge joint.

3d, The combination joint, being the ball and socket and hinge joint combined.

4th, The pivot or wheel joint.

5th, The sliding joint.

6th, The suture or immoveable joint.

Each of these kinds has its peculiar advantages, and even of the same kind there will be found some variations of form in different instances, to suit its position and requirements.

133. Of the ball and socket joint there are two examples in the shoulders and two in the hips. The latter form the most complete specimens of this variety of articulation. The principal superiority of this species of joint consists in the great latitude of motion which it admits of. It is formed by the end of a long bone being rounded into a large, smooth head or ball, which is inserted into a cavity or socket made in the opposite bone of the

joint, and in which the ball revolves in every direction.

Fig. 44.

H *b*, portion of the Hip bone, in which is excavated the socket, S, of the joint. T *b*, the Thigh bone. H, its head, the ball of the joint. N, the neck of the Thigh bone. P, a projection for the attachment of powerful muscles.

134. In the hip joint, the cavity forming the socket is made directly in the body or substance of the hip bone, and its edge is slightly raised above the plane of the bone. But this depression

in the bone is not by any means deep enough to keep the ball in its place ; its depth is, therefore, very much increased by a border of cartilage (which is next to bone in hardness), which is raised about half an inch, and inclines a little inward, so as to embrace the head of the thigh bone. It will be perceived, that the greater the depth of the socket, the less freedom of motion must there be to the thigh bone, but the greater must be the security against dislocation. If the socket were made more shallow, the joint might have had a freedom of motion incompatible with its safety ; even as it is, the ball is forced out of its socket frequently by violent twistings of the limb.

135. But this raised edge of the cartilage alone would not have been a sufficient protection against its displacement ; and we find it most happily furnished with other preventives against such a sad accident. These consist of a peculiar substance called *Ligament*, which has the strength nearly of tendon, and is equally pliable. There are two ligaments in the hip joint very different from each other in form. Both may be seen represented in fig. 45. One is in the form of a short cord, and lies *within* the joint, passing from the head of the thigh bone to the centre of the socket, connecting them together ; and being very firmly fastened to the bony substance at each end, it serves to keep the ball from slipping from the socket, unless force is applied sufficient to break it. It is long enough to allow the greatest extent of motion requisite to the joint, and not so long but that it will keep the ball within its proper limits. From its form it is called the *Round Ligament.*

Fig. 45.

R L, the Round Ligament. C L, the Capsular Ligament, cut open to show the interior of the joint.

136. The other ligament is, from its shape, being that of a bag or cap, called the *Capsular Ligament.* This is situated *outside* the joint, and surrounds it completely, so as to conceal it from view. If the reader will suppose the ball of the joint to be in its place in the socket, and then a broad band to be wound once around the two, so as entirely to embrace them, and fastened to each by its edges, he will have a good idea of the situation of the capsular ligament. In fig. 45, part of this ligament may be seen. It is, in fact, a cylinder in shape, of which one end is attached to the circumference of the socket, and the other encloses the ball. This ligament is quite loose around the joint, so that it does not interfere with its motions; it exerts also

some power in preventing dislocation; but when this accident does occur, it is ruptured by the head of the thigh bone being forced through it. One of the most important uses, however, of this ligament, is to retain within the joint the lubricating fluid, some of which might otherwise escape.

THE MEANS TO PREVENT WEAR AND FRICTION.

137. It will be obvious to all who examine this structure, that if the bare surface of the ball were presented to the like surface of the socket, that is, if the two *bony* surfaces were allowed to rub against each other, it would take but a little while, with the almost incessant action of this joint, to wear them both away so as to be useless, and require a long time to renovate them. The manner in which such a result is guarded against, is simple and effectual, as well in giving smoothness to the rubbing surface, as affording protection to the bones. Each opposing part is covered with a coating of *cartilage*, whose endowments of elasticity and glairy smoothness afford surfaces the most complete imaginable for all the purposes of a joint. Were it the case even that no means had been given to increase their natural smoothness of surface, the cartilaginous faces of the joint would have been almost sufficient of themselves to prevent injurious friction; but, as if nothing short of absolute perfection would satisfy the Great Architect, there is added to this mechanism a little apparatus for furnishing a lubricating fluid, which removes every possible chance of friction. Immediately between the ball and socket of the joint

lies a little sac which has no opening, denominated anatomically a *shut sac*. This sac is large enough to cover the head of the thigh bone, one side of it lying in contact with its surface, and the other side of the sac being adapted to the surface of the capsular ligament, and, in fact, every part of the internal surface of the joint is closely lined with it. It therefore partakes in every movement of the parts. Upon its internal surface is exuded the lubricating material, which is called *Synovia*. It resembles a thin jelly in consistence, and has an incomparable slipperiness and unctuous feel; and always existing, in a healthy state, in sufficient quantities, and being continually renewed as it is exhausted by use, the articulating apparatus is thus kept in a pliant condition, ready, at the bidding of a thought, to operate with perfect smoothness, and with the least possible degree of obstruction from friction.

138. Another source of strength to the joint, and as effectual a one, is the muscles which lie around and cover it to the depth of several inches, and which are the means of its motion. These muscles are the most powerful in the body, and form the large masses of flesh which give the hip and thigh their great size and rotundity. They are attached chiefly by one end to the hip bone, and passing down over the joint, are inserted, some into the thigh bone, and others go as far as the leg, passing over the knee joint. These great bodies of fibres, when they contract, not only bend the joint, but also pull the thigh bone close up against the socket, and firmly keep it in its place, thus greatly aiding to prevent a dislocation. But when

this accident does occur, these muscles exert as much force in preventing the return of the bone to its right place as they before did in keeping it there.

139. There is one other point to describe to complete the articular structure. By examining the shape of the thigh bone in the figure of the skeleton, it will be seen to be of nearly uniform thickness in the middle (called the *shaft*), but at each end it becomes much enlarged in diameter. This enlargement at these points is a wise provision to enable the bones to form stronger joints; for it is evident, the greater the extent of surface in the opposing bones, the more secure may the joint be made. In the joint now under consideration, the head of the thigh bone, which forms the ball of the joint, stands out from the shaft at nearly a right angle, and is united to the shaft by a narrow strip, called the *neck*. This deviation from the line of the bone is given to the neck and head for the double purpose of presenting a firmer position to the whole body when standing, and a more convenient arrangement for the movements of the lower extremity. The head of the bone, the neck, and the large protuberance to which the neck is attached, are all of greater diameter than the shaft of the bone; the first two for the purpose already mentioned, and the latter to give a better place for the attachment of powerful muscles. The casual observer of this difference of size in the different parts of the bone, would probably infer that a corresponding increase of weight must accompany this enlargement, particularly when told that it is not diminished in strength. But such an accom-

paniment would not comport with the boundless wisdom displayed in every other minutiæ of the animal economy. The *internal structure* of the bone at these enlarged parts is such as to avoid the supposed increase of weight, while it loses none of its strength.

Fig. 46.

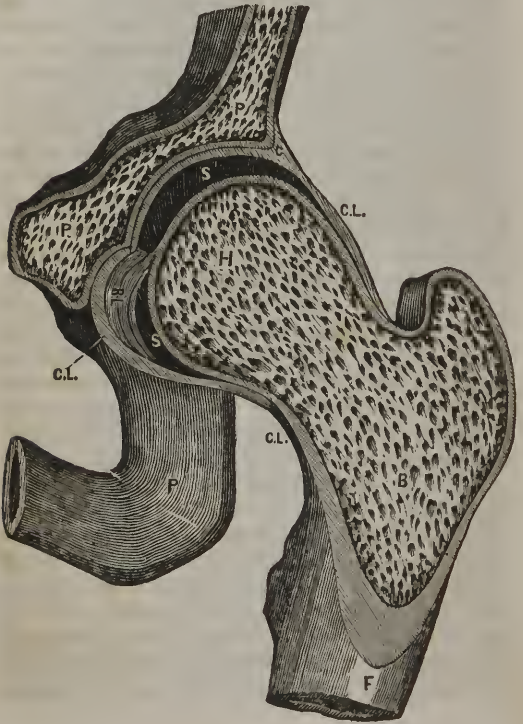


Fig. 46 represents a view of the Hip Joint sawn vertically through, to show the internal structure of the bones which form it. P P P is a part of the pelvis sawn across; F the upper end of the femur; and H the head of the thigh bone also sawn through. R L the round ligament. C L, C L, the edge of the capsular ligament (as it is cut open), embracing the neck of the thigh bone, and extending to the edge of the socket S S. C, a section of the cartilage on the edge of the socket, which serves to deepen it.

The speckled appearance of the bone exposed by the saw represents a structure of numerous little cells, formed by thin laminæ of bone extending across the interior of the bone in every direction. It resembles very much the formation of the common sponge by its numerous and variously-sized cavities. This spongy structure is contained within a covering of bone of a much denser character, but not very thick, which forms the surface of the bone (fig. 46). The same arrangement is shown also in the interior of the thick part of the hip bone. These little cells communicate with each other and with the canal in the shaft, and are filled with marrow during life.

A very simple experiment will prove that this enlargement, while it adds to the capacity and safety of the joint, does not increase the weight of the bone. A section of the shaft of the bone (where the material is far more compact), of any given extent, say an inch, will weigh just the same as a section of equal length taken from the end of the bone, though the latter will have so much greater breadth.

There is another very valuable end answered by this spongy structure, the consideration of which must be left for another chapter.

140. The shoulders present the only other example of the ball and socket joint in the human body. With a few variations, adapting them to their position and uses, the structure of these joints is essentially the same as those of the hips.

There is in these joints a much greater latitude of motion than in the hip joints, as any one may be convinced by a self-examination. The upper extremity may be swung round so as to describe more than a full circle, while the rotations of the lower extremity are confined within that figure. This great difference is attributable principally to the shallowness of the socket, and a corresponding diminution of size in the ball, aided by the mobility of the shoulder blade, the bone in which the socket is formed.

The mechanism and furniture of the shoulder joint, with one exception, are the same in principle and effect as those already described as belonging to the hip joint. The exception is the total absence of the *round* ligament connecting the ball with the socket. A deficiency, however, which is nearly compensated for by a peculiarity in the situation of a strong tendon of one of the muscles of the arm, which passes through the capsular ligament (O, fig. 37), and is inserted near the edge of the socket, in the shoulder blade. This deficiency, and the diminished depth of the socket, while they give the arm its immense superiority of motion, render it, at the same time, less secure than any other

joint. It is, of all the articulations of the body, the most liable to dislocation.

A notice of several of the peculiarities of this joint must be left for the chapter on the "Hand."

THE HINGE JOINT.

141. The articulation last considered admits of motion in every direction; but in those of the second class, the motion is limited to two directions, like the hinge of a door.

The knee and the elbow present the largest examples of the hinge joint, though the joints of the fingers, toes, ribs, and jaw are of the same character, and equally complete. The nodding and beckoning motions of the head are also instances of this kind of joint, but the rotation of the head is by a totally different species.

Although there are two bones in the leg and two in the lower arm, only one of each enters into the composition of their respective joints, as will be seen by examining the accompanying figure of the knee joint.

The other bone in each limb participates most largely in the ankle and wrist joints. By referring to the figure of the skeleton, the two bones which form the leg will be seen to have each one end much larger than the other, and the large end of one bone to be joined to the small end of the other. The large end of each bone, therefore, forms part of each joint, one of the knee, the other of the ankle, while the small end of each has no very close 'unction with the joint; though at the ankle there

Fig. 47.

Skeleton of the Knee Joint. T b, the Thigh Bone. T, the *Tibia*, or large bone of the leg. F, the *Fibula*, or small bone of the leg. P, the *Patella*, or kneepan.

is an exception, both bones assisting to form the joint.

142. The artificial hinge, as every one knows, has its two parts kept together by a pin passing through holes in their edges, which forms also the pivot on which the hinge turns. The motion of the hinge joint being precisely analogous to that of

the artificial hinge, it becomes an interesting inquiry to know how the *bones* are held together; whether by a pin, or some other means as effectual?

When we examine the dry bones of a skeleton, we cannot perceive the least trace of any provision, at the joints, for fastening the bones together; all we can see are the smooth, rounded surfaces at their ends, where they rub against each other, and by which we can tell the extent of the motion of the joint. There are no means to be seen in the dry skeleton by which the bones will even hang together, much less endure the powerful pulling and bending to which they are exposed during life.

There are two principal means of effecting this purpose, both of which have been noticed in the description of the hip joint, and which are applied to the hinge joints in a similar manner, with such variations only as the shape and motions of the joint require. These means of union are ligaments, assisted by the muscles and their tendons.

143. The motions of a hinge joint, as has been said, are only two in number, and they are called *flexion* and *extension*. Thus, when the knee joint is bent, so as to bring the foot up towards the hip, the joint is said to be *flexed*, and when the leg is stretched out in a straight line, it is *extended*. There is no limit to the flexion of the joint except what is caused by the contact of the leg and thigh; but the extension of the joint is limited to the straight line. This limitation is effected in the knee by strong ligamentous bands placed behind the joint, which go from one bone to the other, and which are on the stretch when the limb is extend

ed. This motion is also controlled by the *hamstrings*, the strong tendons of the powerful muscles at the back of the thigh, which bend the joint; they put a check upon the contractions of the extensor muscles, which lie on the front of the thigh.

144. There is in the elbow joint a totally different mode of preventing too great an extension of the limb. This is a peculiarity in the shape of the bones. At the lower end of the *humerus*, which is the bone of the upper arm, is the articulating surface of the elbow joint, and at the back part of the bone is a deep depression (fig. 40). At the upper end of the *ulna*, which is the large bone of the lower arm, is a corresponding surface, to fit against the surface on the humerus. There is a prolongation of the ulna backward (see lever of 3d kind), shaped somewhat like a hook, forming the point of the elbow, on which we lean, which does not interfere with the flexion of the elbow, but which, when the arm is extended, falls into the cavity in the end of the humerus, and, striking against it, prevents a farther extension of the arm. The motion of this part may be felt readily in one's own p son. This peculiarity in the elbow is a great safeguard also against dislocation, besides affording a very convenient point for the attachment of the extensor muscles of the arm.

145. The knee joint presents some strongly-marked peculiarities, worthy of notice as evidence of a *contriving wisdom*, which can *invent* means to accomplish its desired ends. This is the largest and most complex joint in the body; the position in which its several bones lie with respect to each other, when viewed in the skeleton, the flat ends

being merely placed against each other, would lead one to suppose that a displacement would be very easily effected, and yet there is scarcely a joint in the body less frequently dislocated. Its wide exposure in front, its great prominence in every position of the body, whether in sitting, lying, walking, or riding; its liability to injury from falls upon the knees, violent twistings of the limb, and the edges of sharp instruments; and, not less than either, its subjection to the weight of the body, and its uninterrupted exercise for long periods, are fertile sources of supposition that great care would have been bestowed upon the construction of so highly important an organ. We accordingly find it provided with additional means for facilitating its motion, for giving it ample strength, and for protecting it against external injury.

For the attainment of the first end, besides the cartilaginous coverings of the ends of the bones, this joint is furnished with two additional flat pieces of cartilage, called, from their shape, the *semilunar* cartilages. These are thinner at the inner or concave, than at the outer edge, are placed loosely between the bones, and give a greater surface for the extension of the synovial membrane. They operate upon the principle of *friction wheels*, inasmuch as they participate a little in the movements of the bones, receiving and retaining, as it were, a portion of the friction, and, in a considerable degree, diminishing that between the bones.

To give sufficient strength to the articulation, the bones are numerously supplied with dense and strong ligaments passing from one to the other, each being fastened firmly by its ends to the re-

spective bones, and all being so situated as not to interfere with the flexions of the joint, but keeping its extension within the proper limits. Two of these ligaments are placed near the centre of the joint, and cross each other in the form of the letter X. Hence they are called the *crucial* (or cross-like) *ligaments*. Others are placed at the sides and behind.

The latter act chiefly, as before stated, to restrain an excessive extension of the knee.

146. To give protection to the knee joint, both in its various exercises and against the accidents to which it is continually liable, there is situated directly in advance of it a *shield*, made of thick bone, and moveable, to accommodate the different positions of the organ. It is called the *Patella* or *kneepan* (fig. 47), and can be distinctly felt and moved slightly from side to side. This little bone is the connecting link between the extensor muscles, lying on the front of the thigh, and the tendon which unites them to the bone of the leg.

The knee joint has no regular capsular ligament, but its place is mostly supplied by the ligaments which keep the bones together, aided by the kneepan in front. With the exceptions already described, the formation of this joint is similar in effect to that of the hip. Its synovial sac is very large, touching every part of the joint where motion is made, and is copiously supplied with the lubricating liquid.

Behind the kneepan is situated a mass of fat, of loose texture, which, with the synovial fluid, gives perfect freedom of motion to this bone.

147. Every hinge joint in the animal body is

provided with the same arrangement in effect as the knee, however small it may be in size or limited in its motion.

These are, however, the only joints, except those of the jaw, provided with the additional friction-saving cartilages, and for the obvious reason that no other is subjected to such severity of labour and pressure, except that it has some other arrangement by which the *direct* impulsion of the force is obviated. Thus, in the hip joint, the ball not being in a direct line with the shaft of the bone, the direction of the force of the weight of the body is *oblique;* but in the knee, the bones being placed perpendicularly upon each other, like the two parts of a pillar supporting a house, the pressure is in a direct line through their ends, causing a corresponding degree of attrition, and a proportional requisition of means for avoiding its effects; a requisition beautifully answered, as we have before seen. In the ankle, which is the only other joint which receives the weight of the body, there is again another mode by which the direction of the force is refracted and its effects diminished. This will be considered in another chapter.

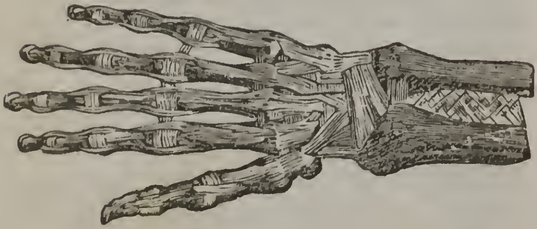
148. The articulations of the lower jaw are subject to as great a *quantity* of motion perhaps as any others, being a part of the organs of voice, and in continual operation during mastication, in which latter action, too, they are of themselves subject to very forcible compression. A means of obviating the injurious effects of these actions is given by little additional cartilages, one in each joint, placed between the bones, separating them completely from each other. They conform to the shapes of

the bones, being slightly convex above and concave beneath, and thicker at their edges than at their centres.

"Sometimes, when the synovia becomes deficient or too much inspissated, the sliding backward and forward of these little intermediate cartilages during mastication produces a crackling noise, audible to by-standers, and exceedingly annoying to the individual who is the subject of it, from the noise being so near his ear."

Of the other hinge-like joints of the body, there is nothing more to be said than that they all correspond in their general formation, each being adapted by some peculiarity to its particular position and office.

Fig. 48.



Bones of the Hand, with some of the ligaments which bind them together. At the wrist the ligaments are particularly numerous, running from bone to bone in all directions.

149. The *third kind* of joint is exemplified in the structures of the ankle and wrist; the latter will be described in the chapter on the "Hand," and, being the more complete example of the two, its view will suffice for both.

150. Of the *fourth kind* of joint, there is but one instance in the human body, which is at the upper end of the spinal column, and is that whereby the head obtains its means of *rotation*. We have stated that the forward and backward motions are

Fig. 49.

Fig. 50.

performed upon a hinge joint, between the head and the uppermost bone of the spine. That joint can admit of no other motion, and the *rotary motions* by which the head is turned from side to side are performed by the revolving of the first bone of the spine upon a pivot jutting up from the second, in a manner similar to the motion of a wheel upon its axle. The preceding figures will explain this arrangement.

A A A, fig. 49, represents the *Atlas*, or first vertebra of the spine. It is merely a ring of bone, with bony projections at the sides. J J are the two articulating surfaces, lined with cartilage where it is jointed to the scull. L is a short, strong ligament, dividing the circle into two parts of unequal dimensions. A A A, fig. 50, represents the second vertebra, with J J, two articulating surfaces, by which it is slightly jointed to the under side of the atlas. P is the pivot of strong bone, standing perpendicularly from the body of the vertebra, and shaped somewhat like a tooth; hence it is called the *Dental Process*. Let the reader suppose the atlas to be placed upon the top of the second vertebra, and the pivot projecting up through the smaller hole made by the ligament in the atlas, and he will have a correct idea of the exact position of the two in the living body. The pivot may be observed to be smaller near its base than it is near its point. It is around this narrow part that the ligament of the atlas binds it firmly, like a collar, while the thicker part above prevents its slipping from its position. On the front of the pivot is seen an oval surface, which is applied to a corresponding surface within the circle of the atlas. These being the points where the principal attrition oc-

curs in their motions, they are lined with cartilage, and have synovial membranes like other joints. A similar apparatus is found where the pivot touches and moves against the transverse ligament.

Fig. 51.

Figure 51 shows these two bones in their natural position; the pivot of the lower within the ring of the upper.

With this curious little apparatus are all the rotary movements of the head, within certain limits, performed. When a very extensive rotation of the head is required, the whole spine, particularly the upper part, is brought into action to assist it, by a complex arrangement of that wonderful apparatus hereafter to be described. This, however, must be more properly considered a twisting of the body than a mere rotation of the head.

151. This last action, the twisting of the body, is the result of a combination of a number of small movements of the vertebræ, or individual bones of the spine upon each other; these movements, when separately considered, constitute instances of the *fifth kind of joint*. The spine is the only part of the body where this peculiar motion is to be found, and its description will, therefore, with more propriety, be given in connexion with that of the spinal column.

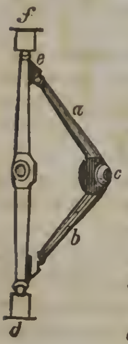
152. The *sixth kind of joint* is an immoveable union between two bones; a union by which two or more (generally flat) bones are fastened together by their edges so firmly as to be without

the least motion upon each other, and yet to retain entirely their individuality, and capability of being separated from each other. It is called the *Suture*, from the Latin word *suo*, signifying to sew or stitch together. It presents a great many interesting and valuable peculiarities; but its chief utility being necessarily described in the formation of the scull, where it is most aptly situated, its consideration will be postponed till the architecture of this organ comes under review.

THE TOGGLE JOINTS.

153. In many machines in which the mechanic wishes to obtain great power with very little motion, he frequently employs an instrument called the "Toggle Joint." This is composed of two levers, connected together at one end by a hinge. The two parts of the instrument stand in precisely the same relation to each other as do the two parts of the arm united at the elbow, or as the thigh and leg united at the knee.

Fig. 52.



The toggle joint is employed in that form of the printing press which is wrought by hand, where it serves to force the paper down upon the types, a movement which is required to be of considerable force, of great uniformity, and of very little extent, for all which purposes this arrangement is exceedingly well adapted. It is a contrivance by which one man may exert a very great degree of power.

Let *a* and *b* represent the two arms of a toggle joint, connected by the ends

at *c*. If the end at *d* is fixed, and the end at *e* is moveable, when the two arms are forced into a straight line, as *f d*, any weight placed upon *e* must be raised to *f*. If *e* were fixed and *d* moveable, as in the printing press, the movement would, of course, be in the reverse direction. Now the power necessary to extend or straighten this instrument is very small in proportion to the force acquired by so doing.

All the joints of the body, except the fourth and sixth kinds, act upon this principle. Take, for instance, the lower extremity. When an individual places himself in a slightly stooping posture, i. e., with his ankle, knee, and hip joints a little flexed, he may, by simply straightening his joints, raise a weight placed upon his shoulders far heavier than in any other manner, though it will be through a very small space. In fact, the exercises of walking, running, and leaping are performed chiefly by the successive and rapid or forcible action of the natural "toggle joints." The great power exerted by beasts of draught and of burden is very much through a structure of their limbs on this principle. Thus, when a horse has a heavy load to pull, he sets himself to the task by fixing all his joints, particularly his hinder ones, in a flexed position, and then, making his feet the fixed points, straightens his limbs, by which his body (to which the moveable ends of his toggle joints are fastened) is thrust forward, taking the load with it. By this mechanism the animal is enabled to overcome a resistance much beyond the mere weight of his body. So (admitting fable to be fact), when the farmer, in answer to his petition for assistance,

was commanded by Hercules to exert himself to raise his wagon from the pit, he placed his shoulder against the wheel, and drawing his body up into a crouching attitude whereby all his joints were flexed, and making his feet the fixed points, by a powerful muscular effort he straightened the toggle joints of his limbs, and the wheel was raised from its bed of "miry clay." His horses at the same moment extending their joints, the heavily laden wagon was carried beyond the reach of farther detention.

CHAPTER VII.

PHYSIOLOGY AND EFFECTS OF EXERCISE.

154. After what has been said of the circulation of the blood and of muscular action, the reader may be prepared to understand a few remarks upon the close connexion and the great influence of the two upon each other, and to follow us in a few deductions on the importance of attending to the functions of one of them in his own person, so as to obtain the greatest amount of benefit to both; in other words, so to regulate his bodily exercise as to ensure the greatest degree of health.

In page 104 we have stated that the ultimate particle of muscular fibre appears very much to resemble the ultimate globule of the blood, both in physical form and chemical composition, as if the

latter had been simply deposited from the vessel without change. Physiologists, however, differ very much with regard to their identity; but, be it as it may, one thing is very certain, that from the extremely minute degree to which the arteries ramify in the substance of muscles, it is hardly possible to distinguish between each final molecule of a muscular fibre and the capillary artery supplying it with blood.

In fine, the muscular fibre appears to be very similar in structure to the coagulum or solid part of the blood. And it is well known, also, to every anatomist, that the supplying artery divides and subdivides to an incalculable extent in every muscle, thus forming a very minute and intimate connexion between each other. It is likewise a well-established fact, that the quantity of blood transmitted to each muscle depends altogether upon the demand for it, the demand being chiefly regulated by the amount of labour performed by the muscle. Thus, if a muscle is regularly and frequently exercised, a greater amount of blood is carried to it than if it is allowed to remain a long time quiescent.

155. The muscles of a man's body constitute more than half his bulk, and, consequently, a very large proportion of the whole quantity of his blood is devoted to supplying them with nourishment. By continued exertion, their energy and material become rapidly impaired and reduced, and can only be restored by an increased activity in the circulation.

"The manner in which this is brought about

will be better understood by examining the annexed engraving of the bloodvessels of the arm.

Fig. 53.

"The letters A B C D E represent the principal muscles of the arm; and F G H I K M N those of the forearm, though they do not appear exactly in their natural positions. The letters in italics refer to the *humeral* artery, which is seen dividing at the elbow into two branches. The one called the *radial* artery, passes on the outer side of the forearm towards the thumb, and is the branch in which the pulse is generally felt; the other, called the *ulnar*, passes along the inner side of the forearm.

"In the natural state, these bloodvessels are covered and protected in almost their whole course by the adjacent muscles, which they furnish with blood by their thousands of branches. In consequence of this position, the muscles cannot contract without at the same time compressing the bloodvessels and propelling their contents forward. The assistance afforded to the circulation of the blood by this arrangement is familiarly exemplified in the operation of bloodletting from the arm. When the blood stops or flows slowly, it is customary to put a ball or other hard body into the hand of the patient, and desire him to squeeze and

roll it about. The success of this action depends simply on the muscles of the arm compressing the interjacent bloodvessels, and forcing onward the current of the contained blood by their successive contractions."

156. The increased activity of the circulation, thus induced by general muscular action, is not confined to the circulation of the muscular vessels, but the whole frame partakes, and every organ and every texture feels its good influence. Not only is the circulation itself invigorated, but a greater quantity of blood is required to supply the demand; it passes through the lungs more rapidly and in larger quantities, which urges the respiratory organs to more active operations in order to purify the blood with sufficient rapidity; while, to supply the demand for *quantity* of blood, the appetite is excited, more food is eaten, and the digestive organs partake of the excitement. Thus, directly or indirectly, almost every function is impelled to increased activity, and the whole system receives a healthy impulse.

157. Illustrations of these facts, as well as of the reverse, may be daily met with, especially in the crowded city; we find there that many who lead active and even laborious lives are in possession of good, vigorous constitutions, healthy looks, and frames that will endure an almost incredible amount of labour, while we also see hundreds equally well prepared in early age for a state of body so very desirable, but who, by a course of sedentary and inactive pursuits, are thin, pale, without muscular strength, and subject to a variety of disorders.

The farmer who daily exerts all his muscular energies in tilling his ground or harvesting his crops, not only is more healthy and strong, but has a clearer head and stronger intellect than the votary of commerce or of letters who confines himself to his chair, and wields nothing heavier than his pen or his books.

The difference between these two opposite conditions is justly attributable mainly to the *non-employment*, in one case, *of the muscular system*, and to its *regular and continued exercise* in the other.

158. By a uniform and moderate exercise of individual muscles, it is well known that they will increase greatly both in size and strength. So much more blood is sent to them when kept in action, a greater deposition of substance necessarily takes place. This is exemplified in the cases of various artisans who have occasion to employ different sets of muscles. With the blacksmith, who is daily in the habit of striking with a heavy hammer, or in lifting massive bars of metal, we shall find the muscles of the arms so large as to appear almost deformed from their size, and possessing proportionate strength and hardness; while the muscles of his lower limbs, used for but little else than to keep him in an erect posture, present nothing remarkable. On the contrary, we find the muscles of the legs of the dancing-master, which are used to throw his body into a thousand different attitudes, and with great force and rapidity, large and firm; while the muscles of his arm, having to perform no mightier feat than to push the fiddlebow, are small and weak.

There is a corresponding difference in the *col-*

our and *structure* of the muscles. That which is well exercised has a healthy, florid appearance, with a firmer and larger fibre, and has a greater degree of fulness; but the muscle which has lain inactive for a long time is pale, soft, and flaccid, and is easily torn in pieces.

159. But to increase the size and strength of a muscle to the greatest degree, its exercise must be *uniform* and *not excessive*. The intervals of relaxation from labour should be frequent, in order to give the muscle and its nerve opportunity to recruit their powers. It is very easy to propel the action of a set of muscles beyond their strength, a circumstance which every individual has made known to him, when it occurs, by the production of a painful sensation in the organ, called *fatigue;* and if this occurrence is not regarded, and the muscles are still continued in action without rest, their energies may at last become so far exhausted as to cause unpleasant results, requiring at least a long period of inaction to recover them, and their contractile power *may* become permanently impaired. Every one is aware how often an active child will sleep during the day; its muscles in its waking hours are almost constantly in action, and, though they may not be doing any laborious work, they soon become exhausted, and call for frequent intervals of repose.

For nearly the same reasons, a muscle should never be exerted to excess. One strenuous effort, especially of a muscle unaccustomed to work, will oftentimes exhaust it completely; in fact, instances are not very rare in which the fibres of a muscle have been torn asunder by too powerful a contrac-

tion, a condition which may be recovered from, but only after days or weeks of perfect rest.

160. Many of the muscles of the lower extremities are employed, when a person is standing upright, in keeping the body in the erect posture. One of the most admirable points in our mechanism is, that so large a mass as is the body is capable of balancing itself so readily and with such surprising facility on so small a base as the feet. We are scarcely conscious of any exertion when standing still, and yet the muscles alluded to are continually in action to keep us from falling. That it is not a trifling exercise of their strength is well proved by the short time in which they become fatigued, and by the relief which we continually endeavour to afford them by a frequent change of position; resting now on one foot, and then on the other.

These are not, however, the only muscles employed in this duty. They are very materially assisted by a range of powerful muscles placed on the back, and lying in the angles made by the projection of the spinous processes of the vertebræ, and to which they are firmly attached. The spinal column, being very flexible, has a constant tendency to incline forward or to one side, on account of the weight attached to it above and at the front and sides, and it is the especial province of this set of muscles to maintain the perpendicularity of the spine, for which they are, by their structure and strength, well adapted. The muscles of the lower limbs only act to keep the body upright while standing, at which time those of the back are in action also; but when we are sitting, the latter

alone are exerted. When we call to mind that, in addition to this, these muscles are generally exercised uninterruptedly during the twelve or even twenty waking hours of the adult, it will readily be believed that not only are they prepared, by their structure and position, but that it should be our care so to cultivate their strength as to render them better able to discharge their onerous functions.

Hence we learn the reason of the severe feeling of fatigue and lassitude which is so common in the back, especially at the lower part of it. The muscles placed low down on the spine must be exerted more than those above, in keeping the body erect, and they become, therefore, more speedily exhausted.

With regard to their structure, we find these muscles made of very strong fibres, and very numerously interspersed with strings of tendon. The tendons appear to be closely incorporated with the substance of the muscle, and are not placed there merely to assist in the *attachment* of the latter to the bones, but also to aid in uniting the different parts of the muscle with each other; this mixture of tendon with the fibres of the muscles greatly diminishes the liability of a rupture of the latter, which might ensue from their great length, and powerful and long-continued contractions.

161. The course already alluded to as the proper one for increasing the size and power of a muscle or set of muscles, applies here as especially necessary. These muscles, having a continual duty to perform, will, if left to themselves, and

unaided by external assistance, gradually grow stronger and more able to do their required work. Exercise is their natural food, upon which they will increase and strengthen; the spinal column will then be kept straight; an upright figure and a graceful carriage, but, above all, a free and easily dilated chest, and an exemption from many pulmonary and other complaints, will ensure to the individual a happier and a longer life.

But it is lamentable to see with how large a proportion of our race these principles are neglected or totally repudiated. Not only are these muscles not *educated* as they should be, but by a large majority of the female sex, and by many of the other, they are *not allowed to be exercised* as nature designed. A severe restraint is put upon them, so that they may not even *assist* in supporting the spine and the chest. By strong artificial constriction, the spine is attempted to be held up without aid from the appropriate quarter, and these muscles are so forcibly compressed as to be unable to contract; and it is not unreasonable to believe, also, that the circulation of the blood through them is in a measure impeded. Two powerful causes thus operate to deteriorate them: 1st, Their work is performed by other and artificial apparatus; and, 2d, They *cannot*, if they *would*, perform even a part of their rightful duty. But this is not all or the worst of the baneful practice of tight dressing. One great object of the practice is to remedy a *supposed deficiency* in the straightness or uprightness of the body. Many pursue this course under the false plea that the figure, without some assistance, would be bent forward and to one side, from its

own weight and inability to sustain itself; they point to their offspring, especially to the daughters, who are growing up round-shouldered, narrow-chested, or perhaps a little hump-backed, with meager forms, sallow countenances, and diminished appetites, as evidence of the correctness of their views, and they therefore believe it necessary to remedy the *defects of nature!*

This is done by throwing around the body a jacket of firm, unyielding texture, having in a fold in front a stiff piece of wood or steel, to prevent the body bending forward, with several rods of whalebone at different places in the lateral and hinder parts, to keep the body upright at the sides and back; and the jacket, thus additionally stiffened, is, by means of a strong laced cord behind, drawn very tight, that each piece of whalebone, wood, or steel may have its due effect. Thus the fond parent, ignorant of the laws which should govern the physical education of her daughters, thinks she is doing them a dutiful service, inasmuch as she prevents their growing crooked, and avoids the probability of disease. But it is not even *postponing* the evil day; diseases, such as she dreamed not of, perhaps, from that day take their start. The very deformity she is endeavouring to prevent or rectify is actually produced or made worse by the means she employs.

162. The muscles of the back are entirely adequate to keep the spine erect, if their strength is elicited by attention to them in early age. Habits of walking and sitting straight should invariably be inculcated, but not to an extent, at any one time, to fatigue the muscles; their exercise should

be attended with frequent intervals of repose. Where a disposition in a figure to become bent or to stoop is discovered, a very good practice is to carry a *moderate* weight upon the head a short time daily. Children who sit several hours in school should always have a seat with a reclining back, and the latter ought to be, if possible, curved to correspond with the curves of the spine, having a projection to fit the hollow part, and a depression to accommodate the protrusion of the upper part of the spine. The curves in the spinal column are natural; and a bench or stool, with a back to suit them, affords a support to the spine exceedingly agreeable and no less proper to a child whose muscles are but half developed, and become weary with but little exertion.

In addition to these points, exercise in the open air, of various kinds, but not violent, should be required every day. "Calisthenics" is a branch of education too much neglected in female seminaries; its practice, if well followed, would, without a question, remove a multitude of the bodily evils with which the fairer class of humanity suffer, and render them better able to perform their peculiar duties in later life.

Free and unconstrained exercise of the whole body, in both sexes, has an effect directly upon the spine, as it has upon all other organs of the body; its muscles are strengthened, it is held erect, the chest is thus kept free and expands to its full extent, respiration and circulation advance uninterruptedly, and the whole body feels the good effects.

But it is absurd to require or expect a free exer-

cise of the body of a girl when cased up in a tightly-laced corset; the whole frame must be free to expand and bend, otherwise the exertion becomes soon painful and worse than useless.

The artificial attempts to prop up the body in this way, instead of leaving it to support itself, are very early shown to be inadequate. It has been frequently remarked how very numerous are the instances in modern ladies' boarding schools (and the same will doubtless be found in most private families) of curved spines and uneven shoulders. There is scarcely an example to be found in polished female circles of a *straight* figure. The waist may be attenuated to a fashionably beautiful degree, but an almost invariable accompaniment is the elevation of one shoulder above the proper line, giving the bust a very awkward appearance, and presenting to the eye of the physician sure symptoms of a corresponding derangement in the position of internal organs, whose arrangement cannot be disturbed with impunity.

CHAPTER VIII.

THE HAND.

163. We have now to examine an *instrument* which, for *perfection of mechanism* and *variety of uses*, surpasses every other yet known to man. Apart from the superhuman derivation of its moving power, the wonderful variety and extensiveness, the comprehensiveness and minuteness, the strength and delicacy, the gracefulness and expressiveness of its motions, are utterly and hopelessly beyond the reach of his ingenuity to rival. Man is well known to be far inferior to many brutes in bodily strength; and in acuteness of sense he cannot approach some animals; as, for example, the hound excels him in the sense of smell, the eagle in sight, the hare in hearing, the bat in touch, and so on. Even in sagacity, the horse and the elephant are scarcely his inferiors. But neither of these animals, nor any other, has any one appendage to its frame which, in multiplicity of powers, complexity of mechanism, and number and variety of endowments, can approach the human hand. That part of a brute which corresponds most nearly to the hand of man, is in each class possessed of one or more certain properties particularly appropriate to the character and habits of that class, but those properties are limited entirely to the animal's necessities. Thus the

paw of the lion or tiger is furnished with sharp claws, projectile or retractile at pleasure, the better to seize its prey; but it is thereby deprived of the sense of touch in that member. The fore foot of the horse is armed with a hoof, to enable him more safely to travel the hard road, and to paw the earth as an expression of pride; but he, therefore, cannot grasp a body. The tongue of the chameleon, which answers for its hand, is longer than its body, and is formed into a knob at the end, which is covered with a glutinous substance, against which the insects forming its food adhere when the tongue is darted against them. But the chameleon's hand, if we may so call its tongue, is good for nothing else. The trunk of the elephant and the hand of the monkey, for flexibility, extent of motion, and vital endowments, approximate nearer to the capabilities of the human hand than any limb of any other animal; but the elephant's trunk has no fingers, and the monkey's hand has only a very short thumb. But in the human hand there is a combination, in a large or small degree, of nearly all the peculiarities that characterize the corresponding appendages of inferior animals, or else there is some additional counterbalancing power. Hence, considered as a separate and independent instrument, so beautifully complete is it in its organization, that some writers have expressed the opinion that man is mainly indebted to his hand for his superiority over the rest of the animal creation.

164. But we must not forget, that however perfect an instrument may be, without an *intelligence* adequate to direct its operations in a skilful manner, its great perfection would be unnecessary,

since it could not be brought into use. We must, therefore, view man as superior by his *intellectual strength*, and his hand as an *agent* or *implement* fitted, by a benevolent Creator, to carry into operation the designs of his inventive mind. If we could suppose any priority in the construction, by the Great Architect, of the mind and the hand of man, the correct supposition would be, that the former was first made, and the latter arranged to conform to its requirements: "the hand corresponds with the superior mental capacities." We therefore say, with Galen, that man had hands given to him because he was the wisest creature; and not ascribe his superiority and knowledge to the use of his hands.

The power of reasoning and thinking is the source of ingenuity and contrivance, and not the hand, which is only the implement for executing their suggestions.

If we institute a comparison between the hand and the most ingenious machines that have been contrived by man, we shall find a vast deal to admire in the latter, but nothing that will excite so much astonishment and wonder as are presented by the former.

165. In studying the mechanism and powers of the human hand, we take a very limited view of the subject if we confine our attention to that part of it which embraces the wrist and five fingers only, and our task would very soon be completed. But we shall find that the *whole upper extremity* must be comprehended; for it has indubitably been constructed in its joints, and levers, and muscles for the purpose of enlarging and extending the

powers of the *hand*. To understand this, it is only necessary to imagine how ineffectual would be the hand without the intervention, between it and the body, of the complicated and powerful apparatus of the arm, from the shoulder to the wrist. To gain a satisfactory knowledge of the source from which this extraordinary implement derives all its mechanical capabilities, we must trace the anatomical relations of the whole limb, even to the manner in which the shoulder is attached to the body; and then we shall have but half finished the study. The beautiful arrangement of complex and numerous joints, of delicate tendons, curiously-shaped muscles, and all the intricate apparatus of this organ, would be of but half their present use were they not assisted and directed in their actions by the most refined sensibility. In other words, the hand is not merely an instrument of prehension, or a machine to assist us in protecting our lives or procuring us sustenance, but it is the seat of one of the senses: it is the organ of touch, as the eye is of sight or the tongue of taste. The ends of the fingers are the parts particularly endowed with this faculty, though it is distributed, in a measure, over the skin covering the entire palm. We shall, therefore, be led to study the manner in which the nerves are distributed through the hand, and also to inquire into the nature and character of the skin, and the mode of its arrangement.

166. The bones which compose the upper extremity are (fig. 40) the shoulder blade (*scapula**), the collar bone (*clavicle†*), the upper arm bone

* From the Hebrew.

† From clavis (Latin), a key; from its resemblance to an ancient key.

(*humerus**), the two lower arm bones (*ulna* and *radius*†), the eight bones of the wrist (*carpus*‡), the four long bones of the palm (*metacarpus*§), and the three bones (*phalanx*, plural *phalanges*||) of each finger and of the thumb.

167. The shoulder blade is the broad, flat bone, of a triangular shape, situated behind the chest, and forming the top of the shoulder. It constitutes the irregular projection discernible in all, especially thin people.

This bone is very moveable in a great many directions; it will slide up and down, move from side to side, and slightly rotate on the chest. By placing one hand upon it, and then moving the shoulder about in different directions, or swinging the arm to and fro, the movements of the shoulder blade may be felt. The great diversity of its motions arises from a peculiarity in its mode of attachment to the body, in which it is unlike that of any other bone in the system, with one exception.¶ It has no *bony* union with the trunk of the skeleton. The mode in which it is kept in its place is by being covered over with strong muscles, which run across it in a variety of directions, and which lie so loosely upon it as to present no impediment to its movements. It is entirely separated from the ribs by a thick interposed layer of muscles.

* From the Greek for shoulder.

† Ulna, from the Greek for cubit; radius, so called from its resemblance to the spoke of a wheel.

‡ From the Greek for wrist.

§ From the Greek, signifying after or upon the wrist.

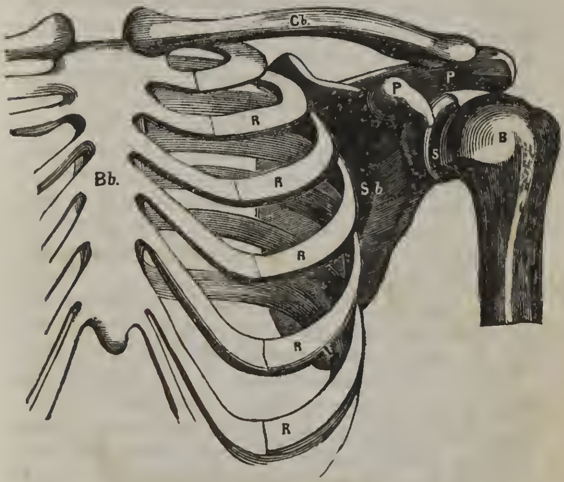
|| From the Latin for a regiment or battalion, because they are ranged like a company of soldiers.

¶ This is the *Hyoid* bone, in the throat.

It is, therefore, not *jointed* to the trunk. It is well supplied with appropriate muscles for all its movements.

168. The only connexion which the scapula has with the trunk is by the clavicle or collar bone, and this serves, not so much as a connecting piece, as a brace to keep the shoulder off from the chest, to prevent its falling forward. The clavicle is that

Fig. 54.



Skeleton of the Shoulder Joint. R R R the ribs of the left side. B *b* the breast bone. S *b* the shoulder blade. C *b* the collar bone. S the socket of the joint formed in the shoulder blade. B the ball of the joint, being the upper end of the arm bone. P P are two projections from the shoulder blade which overhang the joint, to give it protection, and for the attachment of muscles.

bone at the upper front part of the chest which extends from the breast bone across to the shoulder, and forms the prominent ridge above the chest.

The square form of the chest and the free exercise of the hand are very much owing to this bone. It keeps the shoulder apart from the chest, and throws the action of the muscles upon the arm bone, which, but for it, would be drawn inward, and contract the upper part of the trunk.

At both ends the clavicle forms moveable joints, so that it offers no impediment to the movements of the shoulder, any farther than what is the necessary result of its keeping the shoulder braced back.

169. From the position of the shoulder, projecting, as it does, considerably beyond the trunk of the body, it will at once be seen that the arm and hand must have a far greater extent of motion than if the limb had been attached directly to the chest. The looseness of the scapula affords a very large proportion of the extensive swinging of which the arm is capable.

The scapula and clavicle both furnish points for the adhesion of several strong muscles, used to effect the motions of the arm and for other purposes.

170. In the demonstration of the *humerus*, or bone of the upper arm, there are several interesting facts to be observed. In the thigh bone, whose motions are very limited in comparison with the arm, we have seen the head of the bone to stand off two or three inches from the shaft, at nearly a right angle, and also two large protuberances on the shaft near the end, both of which circumstances serve very greatly to restrict the motions of the limb, but are necessary for other purposes.

In the hip also we observed a very deep socket, which still farther impedes the motions, though it adds strength to the joint.

But in the shoulder joint we observe the very reverse of these things. There are elevations on the end of the humerus for the attachment of muscles, but they are so small and depressed that they cannot strike against the shoulder blade; the head of the bone, with its great hemispherical surface for articulation with the shoulder, is almost directly in a line with the shaft, while it and the socket of the joint are both very shallow. All these provisions have evidently been designed to allow the greatest possible freedom of motion to this joint, which, though incompatible with as great a degree of security as other joints have, yet gives that wonderful extent, facility, and freedom of movement so important to the hand.

The *humerus* presents a fine instance of the long bone, being very nearly of a cylindrical form, enlarged at both ends to form the shoulder and elbow joints; hollow in the centre for the lodgment of its marrow and to increase its strength; and its external surface marked with ridges for the attachment of muscles.

171. The elbow joint, formed by the *ulna* of the forearm and the *humerus* of the upper arm, has already been described and its peculiarities pointed out (144).

172. The *wrist joint* has been left for this chapter because it is very peculiar in its formation, being adapted particularly to augment the facilities of motion possessed by the hand.

This and the ankle joint are the only instances

in the body of that kind of joint which I have arranged as the *compound*; the *third* in the enumeration. They both partake of the motions of the ball and socket, and of the hinge; for the reader may see, by examining his wrist or his ankle, that it is capable of *flexion* and *extension* like the knee, and of *rotation* like the hip or shoulder. In describing the *compound joint*, our attention will be confined chiefly to the wrist, as presenting rather the better specimen, referring to the ankle as often as may be necessary for farther elucidation. To understand better the nature of its motions, the

Fig. 55.

skeleton of the arm and hand must be studied as shown in the above cut.

H is the humerus, R the radius, and U the ulna. The ulna and humerus form the elbow joint, the end of the ulna being that process of the elbow on which we lean the arm. W the wrist, or carpus, formed of eight irregular bones, in two rows of four each ; the upper row is articulated with the arm, and the lower row forms the basis of the palm or metacarpus. 1 2 3 4 are the bones of the palm, supporting the bones of the fingers by moveable joints. The thumb has no metacarpal bone, but is attached directly to the wrist.

It will be seen by this drawing, that of the two bones of the forearm, the ulna is the only one entering into the composition of the elbow joint, and the radius alone assists to form the wrist joint. The ulna has nothing to do with the wrist, nor the radius with the elbow. Each bone has a large end and a small end ; the former assisting to make its respective joint, and the latter being somewhat in the form of a button, especially the small end of the radius, which is beautifully round. These bones lie nearly parallel with each other, and the small end of each is placed against the side of the large end of the other, confined to it by circling ligaments, so as to permit one to be rolled upon the other without moving asunder.

173. The motions of the wrist joint are three in number. 1st, The *flexion* and *extension* of the hand. 2d, A motion of the hand from *side* to *side ;* and, 3d, A *rotation* of the hand.

The *first* of these, the flexion and extension, is performed in the same manner as by the hinge joint, by the upper row of wrist bones moving on

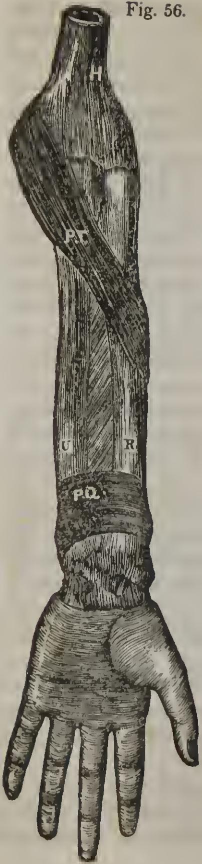
the radius. The *second*, or the *sideway* motion, is produced by the same bones, and is simply a flexion and extension, but in a direction at right angles to the foregoing motions. This motion is employed in writing, when the fingers move from one side of the page to the other, while the arm is kept firm upon the desk. The two motions are combined in the act of repeated beckoning with the hand, when the arm is not allowed to participate. The same motion is producible also in the first joint of the fingers, by which we are enabled to separate the fingers from each other, or slightly to cross them.

The corresponding motion in the ankle joint is that by which the sole of the foot may be turned inward or outward.

This is a very useful power when walking on an inclined surface, as the side of a hill or the roof of a house; we are by it enabled to turn the foot so as to apply the sole fully against the inclined surface, and thus obtain greater security.

174. The *third* is the most curious of all the movements of this joint, and displays a striking exhibition of inventive power. It is that motion by which we are enabled to turn the palm of the hand up or down, producing the positions called *pronation* and *supination*. When the open hand is upon the table with the palm *downward*, it is then in a state of pronation, and when with the palm *upward*, it is supinated; both actions are performed in turning a key in a lock or boring horizontally with a gimlet; it is these different positions that this unique arrangement is made to produce. When the hand is in a state of supination, the bones are placed with respect to each other, as seen in fig.

Fig. 56.



55, lying side by side. But to perform pronation, that is, to turn the hand over, the lower end of the radius revolves around and over the ulna, while its upper end merely rotates in its place. When pronation is completed, therefore, the radius lies obliquely *across* the ulna, and as the hand is attached to the radius alone, it must move as the bone moves. The ulna does not move at all in this action, but is stationary, and the motion is solely effected by the revolving of the radius around it.

The different directions and movements of the radius may be distinctly perceived in one's own arm when these actions are performed.

It is, therefore, strictly speaking, not in the wrist joint that this motion is produced, but altogether in the forearm.

175. The thinking student will be curious to know in what manner the muscles are arranged which cause

these motions. To explain the positions and actions of the pronator muscles, the preceding cut is introduced. These muscles are two in number, and are called the long and round pronator (*pronator teres*), and the square pronator (*pronator quadratus*).

H (fig. 56) the humerus or bone of the upper arm, R the radius, and U the ulna, with the hand supine. P T is the long muscle arising from the ulna, and running obliquely downward, it is inserted into the outside of the radius. The square muscle P Q takes a somewhat similar course near the wrist. By observing the direction of the fibres of these muscles, it will be seen that, when they contract, the radius only being moveable, it will be turned over and its lower end thrown across the ulna, and the back of the hand will then be upward, or pronated. To produce supination, muscles, which are antagonist to these, and called supinators, are placed on the back of the arm, and act in a similar manner, but in a contrary direction.

176. In the hand, including the wrist, are twenty-seven bones. The nineteen appropriated to the palm and fingers are united together by moveable joints, and hence we perceive the source of the almost unbounded mobility of this member.

177. The motions of the fingers are remarkable not more for their extent than for their velocity, a quality bestowed upon them by the unexampled profusion with which they are provided with muscles, by which also they are endowed with surprising strength.

There are thirty-seven muscles attached to the forearm and hand, employed exclusively to perform the motions of these parts; but the muscles whose

use is to bend the finger joints lie upon the front of the forearm, and do not extend lower than the wrist. It has been shown (104), that if the bodies of these muscles, in their full size, had advanced across the palm and had been inserted directly into the fingers, much more actual power might perhaps have been obtained, but the hand would have been so large and cumbrous as to have been totally useless for a thousand delicate and important actions to which it is now beautifully adapted. These muscles, therefore, not being prolonged beyond the wrist, their power is communicated to the fingers through the intervention of long, slender, and powerful tendons, which go across the palm, and are fastened directly to the bones of the fingers.

178. The joints of the fingers are generally numbered for distinction, that next the palm being the first, the middle one the second, and that nearest the end of the finger the third.

The first joint is flexed by a little muscle appropriated to each finger, and lying between the bones of the palm. But the second and third joints are bent by the muscles on the forearm; and their tendons present a beautiful piece of mechanism, which will now be described.

One muscle only is used to bend the second joints of all the fingers (not the thumb), and also one the third joints. Each muscle, therefore, has *four* tendons, one going to each joint.

Two muscles only are thus devoted to this general purpose of bending the fingers down upon the palm. They are called "flexors," while their antagonists are called "extensors." They are so ar-

ranged, that the muscle which bends the *third* joint is placed *beneath*, or nearer the bones, than the muscle which bends the *second* joint. Therefore the tendons of the former muscle, in order to go to their destination, must pass under and *go by* the tendons of the latter. How is this done?

A *slit* is made, as smooth as if by a sharp knife, in the tendons of the second joints, through which the other tendons glide and pass onward.

By this simple contrivance all space is economized, and the fingers are made as small as possible; and had the lower tendon passed by the upper on either side, the finger would have had an uneven shape.

179. The fingers have a great variety of motions besides those of flexion and extension, many of which are extremely delicate, such as those used by engravers and by penmen; the motions of a lady's fingers while sewing or playing on the piano, or of a man's while fingering the violin or the flute, are characterized by their delicacy and extreme rapidity, but none of these require any great degree of strength. A separate class of muscles, of less size than those just described, are devoted to those purposes. They are very numerous, and are situated chiefly between the bones of the palm, and form a considerable portion of the bulk of the palm.

The *flexor* muscles, which have just been described, bend all the joints of all the fingers at once when they contract, and the *extensor* muscles, situated on the back of the arm, extend them all at once, as any one may see by inspecting his own hand. But it may also be seen that some of the

fingers may be flexed and extended independently of the others, as, for example, the first, called the "index" finger, may be fully extended while the others are fully flexed, as in the act of pointing (from which it derives its name), and vice versa. So also with the little finger. These fingers have entirely separate and distinct muscles for bending and extending them, which may act independently or in connexion with the common flexors and extensors.

Perhaps no one thing has been observed more frequently by human beings than the difference in the lengths of the fingers ; and yet it may be questioned whether a reason for any one thing has ever been thought of or sought for less frequently than for this important circumstance.

This shows how unmindful we may be of circumstances which every moment add greatly to our comforts and abilities. When the fingers are bent down so that their ends touch the palm, we see they are all on a line ; or when we grasp a round body, as a stick or a ball, we find that this difference in length enables us to obtain a more secure hold of the object, the longest fingers being around its thickest part, and their ends all even with each other. The difference in length serves also to give us a secure hold and freedom of motion in holding a rod, a hammer, a pen or pencil, or an engraving tool.

THE THUMB.

180. In the preceding descriptions of the fingers, the thumb has not been included, because it is controlled by a set of muscles quite distinct

from those of the fingers, and because it presents some other peculiarities which are worthy of notice. The superiority of the human hand over that of the ourang outang or the monkey, which are all very similar to each other, depends for the most part upon the greater length of its thumb. In these inferior animals, the thumb will be seen to extend no farther than the roots of the fingers, while the human thumb reaches as far as the middle of the fore finger. It has also a very superior degree of flexibility and strength, being nearly equal in those respects to all the fingers together. The large mass called the "ball of the thumb" is formed chiefly of large and powerful muscles; without these, the power of the fingers would avail little; for if we take hold of a stick or a rope with the fingers only, and attempt to pull hard, we shall find that the grasp is feeble and inefficient; but when the thumb is brought over to assist the fingers, the grasp is firmly fixed, and the power of the hand is doubled. "On the length, strength, free lateral motion, and perfect mobility of the thumb, depends the power of the hand; and the large 'ball' is one of its distinguishing characters, especially of that of an expert workman."

181. In concluding this description of the mechanical arrangements of the hand, we have to notice one or two more important circumstances. The muscles, tendons, nerves, and bloodvessels, which lie in great abundance in the palm, are all very much exposed by their situations during its actions; and the power with which the hand grasps, for instance, as when the sailor lays hold to raise his body in the rigging, would be too severe a pres-

sure for these delicate tendons if unprotected. "They would be crushed, were not every part that bears the pressure defended with a cushion of elastic fat; added to which purely passive defence, there is a muscle which runs across the palm, and more especially supports the cushion at its inner edge. It is this muscle which, raising the edge of the palm, adapts it to lave water, forming the cup of Diogenes."

182. The other circumstance to be noticed is the preference of the right hand over the left. Every one knows how common is the fact that the right is almost always used in preference to the left; how awkward, and, in many operations, how impossible it is to use the left hand, and how very few exceptions there are to the otherwise universal rule. It is so likewise with the right foot, and, indeed, with the whole right side of the body. "No boy hops on his left foot unless he is left-handed. The horseman puts his left foot in the stirrup, and springs with his right. With opera dancers, the most difficult feats are performed with the right foot. But their preparatory exercises better evince the natural weakness of the left limb, since these performers are made to give double practice to it, in order to avoid awkwardness in their public exhibitions; for if these exercises be neglected, an ungraceful preference will be given to the right side." Whence, then, comes this superiority in strength and dexterity of the right side? Is it taught, or have we this readiness given to us by nature? Many modes of answering this question have been attempted, such as an increased size and peculiar distribution of the arteries of the right arm; that it

is an effect of habit, &c.; but none of these are by any means so satisfactory as that given by Sir Charles Bell. His manner of reasoning upon this subject is this: "For the convenience of life and to make us prompt and dexterous, it is pretty evident that there ought to be no hesitation which hand is to be used or which foot is to be put forward." Emergencies occur daily to every individual in which there must not be a moment's hesitation which hand is to be employed. Not an instant can be allowed to *think* which of the two would best answer the purpose required, for the least indecision might involve loss or calamity. But such indecision would be very likely to arise if our hands had been constituted equally applicable to the call. Supreme Benevolence has therefore so arranged it, *universally*, that one hand shall have the preference; with a vast majority it is the right, and with the few the left hand. Not only does our safety ofttimes, but more often our comforts, depend upon the readiness with which the right hand can be applied. "The conveniences of life are adapted to the right hand, and these are not arbitrary, but related to a natural endowment of the body. He who is left-handed is most sensible to the advantages of this adaptation, from the opening of a parlour door to the opening of a penknife."

THE ORGAN OF TOUCH.

183. The external covering of the human body is different in many respects from that of any other animal. In every inferior creature, we find some peculiarity in the features of the skin adapted to

protect the animal in the best manner from the injuries to which its habits are most likely to subject it. Thus, birds are covered with feathers, arranged in a most curious and ingenious manner, so as to turn off the rain from its body more effectually than does the tiled roof of a house; they are admirably calculated also to protect the body from cold, and, moreover, are so light as to make no impediment to its flight, but rather to increase its buoyancy by their loose and fibrous texture. Fishes are provided with a covering which is a most effectual preventive of any hinderance to their progress through their peculiar element. Formed of scales, arranged with surprising economy of space, which are light, elastic, and firm, these animals are well protected against the attacks of their inferiors.

In land animals we find provisions suited with equal wisdom to give them protection from external injurious agents. Most of these are covered with material which keeps them warm, as hair, down, and wool, and yet, in many instances, these coverings appear to present but little, if any, impediment to the sensibility of the skin. The horse feels when a fly alights upon his body, and by a rapid action of a muscular layer of the skin, communicates a vibratory motion to the latter, which shakes the insect off. Or, if this is not sufficient to dislodge it, he sweeps over his hide, with singular force, his long and brush-like tail. The elephant and the rhinoceros, especially the latter, are furnished with a covering so dense and hard as to resist a musket ball; but in these animals the skin is totally void of sensibility, as it is also in such

creatures as the lobster, the crab, and the tortoise, which carry their *skeletons* outside, as the covering of their bodies, affording the most secure protections possible.

Now, when we compare these specimens of cutaneous coverings (and numerous others equally diversified might be mentioned) with that which is given to us as our protector against cold, the stings of insects, or the approach of dangerous instruments, we observe a widely different structure from that of any other animal.

184. The natural covering of the human body is very thin, of an exceedingly delicate texture, very easily lacerated, and has no power of retaining the warmth of the body, not being supplied with fur or hair like other animals; but, in lieu of these properties, it possesses a most remarkable *sensibility*, which, so far as the skin is concerned, is the great safeguard of the body.

The changes of the temperature of the atmosphere are instantly perceived by the sensitive skin, and warn us to place ourselves in situations, or to cover our bodies so as to avoid the consequent ill effects. Its sensitiveness is so great, and its nervous endowments are so well arranged, that the most gentle breeze or the lightest feather cannot touch it without being instantly perceived, and the individual's attention being instantly drawn to the precise point.

185. This organ, therefore, placed, as it is, outside of all other organs, being thus the part which must come in actual contact with external objects, and thus provided universally with this acute sensibility, is that which reflection would first fix upon

as the most proper to contain the sense of touch. And were we called upon to say what particular part of the skin would be the most suitable to provide with this sensibility in an extraordinary degree of acuteness, so as to constitute especially an *organ of touch*, can any one doubt that he would decide upon the hand, and particularly the ends of the fingers, as eminently preferable? And so we find it. The hand, in addition to its intricate mechanism and great versatility of powers, is endowed with nervous sensibility to so high a degree as to constitute it the organ of not the least important of the five senses.

This peculiar faculty is distributed in a great measure over the whole palm, which is thus rendered capable of perceiving, with considerable acuteness, the nature of the bodies which it touches; but it is in the ends of the fingers that it is more highly concentrated, endowing these parts with the most refined delicacy of tact, and rendering them especially capable of distinguishing the nature, texture, form, and size of bodies, with the greatest precision and correctness.

186. Most persons have observed a peculiarity in the structure of the skin of the palm and inside of the fingers. By a close inspection, the external layer of the cuticle will be seen to be arranged in very numerous fine ridges or elevated lines, which are much more delicate at the ends of the fingers, and are there also of a semicircular form, and are concentric, the centre being a little prominence on the front of the finger. These lines are to be seen on no other part of the body than the palm and fingers of the hands and the soles of the feet,

where a degree of delicacy of touch is necessary, and it is, therefore, a reasonable inference, that the skin is thrown into this form at these parts to afford a more convenient distribution of the sentient nerves.

In confirmation of this view, anatomy shows that "these ridges have, corresponding with them, depressed lines on the inner surface of the cuticle; and these again give lodgment to a soft, pulpy matter, in which lie the extremities of these nerves. There the nerves are sufficiently protected, while they are exposed to impressions through the elastic cuticle, and thus give the sense of touch."

187. The hand, endowed with the faculty of touch in this exquisite degree, becomes one of the most important organs of the system, apart from its wonderful facility of motion and its great muscular power. The sense of touch is the greatest corrector of the other senses, particularly of the sight. When uncertainty attends the uses of the other senses, if the touch can be employed, it is pretty sure to set them right. As, when the distance of an object or the size of a body is miscalculated by the sight, if the hand can be applied to it, all the uncertainty is immediately dispersed.

But the hand, in its capacity of the organ of touch, becomes more interesting still when employed as a *substitute* for other senses which have become destroyed or are deficient from birth. It bears this relation to the sight more frequently than to any other. With persons who are naturally blind or who become so very young, the touch is generally cultivated to a most astonishing degree of acuteness and delicacy; these unfortunates fre-

quently are enabled to discriminate between things with as much correctness as those who have their sight. Pupils in blind schools are taught to read with great facility, to manufacture various articles of nicety with surprising dexterity, and to perform correctly on musical instruments. Blind people are often seen in cities, fearlessly pursuing their way through the crowded streets, guided only by a stick held in the hand. It has been said, that some blind people have even been able to distinguish colours by the touch. The great Reimarius of Holland, although totally blind, composed a very large and accurate work upon botany, arranging and classifying the plants with great readiness.

A considerable degree of the same kind of sensibility as that with which the hand is gifted, is bestowed also upon the soles of the feet and toes. It becomes, in those situations, a highly important faculty in directing us how and where to place our feet in walking. How instantly are we enabled to discern the nature of the ground on which we tread; how readily can we perceive the form and inclination of the surface beneath us? powers granted us solely by this delicate faculty. To complete the organization of the hand and the foot, their sensitive extremities are protected against injury by the addition to the upper parts, and entirely out of the way of interference with their delicate faculty, of a substance expressly invented (if we may so speak) for the purpose, than which none could better serve the intention. The *nails* are formed of a material *sui-generis*, and which is only to be met with in these organs.

When we consider the various facilities pos-

sessed by the hand, its singular muscular power, and its applicability to so many important purposes, the mind becomes lost in admiration at the grandeur of the wisdom which has made so perfect an instrument, and our gratitude is no less raised to that All-wise Being for his benevolence when we compare the hand with the extremities of other animals, and remember how admirably it corresponds with the reason which elevates us above the brute creation.

"Some animals have horns, some have hoofs, some teeth, some talons, some claws, some spurs and beaks; man hath none of all these, but is weak and feeble, and sent unarmed into the world; but a hand, with reason to guide it, supplies the use of all these."

CHAPTER IX.

THE SKIN.

188. The remarks upon the external covering of the human body in the last chapter will serve as an introduction to a more extended notice of the subject.

It was there shown to differ from the corresponding organ of all other animals, and to possess some properties which none others have. The skins of other creatures serve to protect them either against the changes in the temperature of the

air or the injurious action of foreign bodies, but by modes which are chiefly mechanical, whereas none are so much exposed as is that of man; to compensate for which the latter is endowed with a peculiar sensibility, which is rendered more acute by that very exposure.

189. Although the skin is apparently so very thin, it is composed of *three layers*, which are readily distinguished from each other. The *external* layer is called the *cuticle*, or scarfskin. This, when separated from the others, is seen to be nearly transparent, very thin, elastic, and totally insensible. It is this part of the skin which is raised by the action of a blister, and which frequently peels off from the hands and feet.

Next below this is a layer still thinner than the cuticle, which is called the *rete mucosum* or *mucous network*. It is in this part that the colouring matter of the skin appears wholly to reside, as the others are white or colourless, and this has a decided hue, varying with the individual. Its texture is so very attenuated as to make no perceptible increase to the thickness of the skin.

The deepest layer of all is denominated the *cutis vera* or *true skin*, and this may be considered the most important part of the skin, as it is the only portion which is supplied with nerves, and alone possesses any sensibility. The nerves of the skin are so abundant in this layer, that their extremities are exposed to the contact of the air when the two layers above it are removed.

190. It is the *extremities* only of the nerves, whether of the eye, the ear, or any other organ, which can receive an impression correctly, and the

nerve must have an organ appropriated to its particular purpose. Thus the nerve of vision must have an eye to enable it to receive an impression of sight; the nerve of hearing must have an ear to enable it to receive an impression of sound; so with the nerves of smell, taste, and touch. And to each of these organs, one extremity of its particular nerve is distributed, which receives the impression which the nerve conveys to the brain, and the mind perceives it. Now, if the optic nerve is divided, and a ray of light is thrown against its cut extremity, no impression of light will be received, because the proper apparatus of lenses, transparent membranes, humours, &c., which constitute the eye, do not modify and arrange the light so as to make it perceptible to the nerve. The same would happen with the nerve of any of the other senses.

Another fact to be remembered is, that each nerve has its own particular function to perform, and can perform no other. The olfactory nerve cannot convey impressions of sound, nor the gustatory nerve an impression of light. The nerve which, in the eye, gives the sensation of pain when the organ is inflamed or is touched with a foreign body, is totally distinct from the optic nerve, and that is still another nerve which controls the motions of the eyelids, or of the eye itself, and still another which superintends the opening and shutting of the little gland which secretes the tears (82). The nerves of the skin are entirely distinct from those which control the muscles immediately adjacent.

From these circumstances it is shown that the

sentient extremity of each nerve and the organ to which it is attached assist each other in their appropriate duties.

Yet, with all this great variety of powers and uses, not the slightest variation in the texture or material of the different nerves can be perceived. The only difference is in the *functions* of the nerves. "Experiment proves what is suggested by anatomy, that not only are the *organs* appropriated to particular classes of sensations, but that the *nerves*, intermediate between the brain and the outward organs, are respectively capable of receiving no other sensations but such as are adapted to their particular organs. Each organ is provided for receiving a particular influence, and no other."

191. The "true skin" being the only part of the skin supplied with nerves, when the other layers are removed, the extremities of these nerves are directly exposed to the contact of other bodies. The *cuticle*, being an insensible substance, forms a complete covering to the nerves, so that when a substance touches the skin, the external coat intervenes completely between the object and the nerves, and a direct contact cannot take place.

This might by some, at first thought, be considered a defect in the organization. Some physiologists have maintained that the scarfskin is an accidental production, formed by the hardening of the true skin. Neither of these ideas is at all consistent with the views which should be always entertained of the wisdom of the Creator.

There is no imperfection in the whole system, nor is anything left to chance. The latter suggestion is shown to be untrue by the fact that the cuti-

cle is perfect in the newborn infant, and even then is thickest on the hands and feet, as it is in after life. And the first notion is entirely subverted by the many important uses to which the cuticle is known to be subservient.

Let us suppose the cuticle to be absent entirely, and the true skin to be exposed to the contact of foreign bodies.

Provided as these nerves are with an exalted degree of sensibility, and required to exercise their functions in the most delicate manner, were they to be actually touched by the substance to be felt, the refined material of the nerve would be too much compressed and bruised, even by the lightest pressure of the softest substance; and instead of receiving an impression suited to its delicacy, it would convey only a gross, obtunded feeling, or perhaps the sensation of pain would be excited, irritation and inflammation would be produced in the sensitive texture, and, by degrees, the nervous extremities would become thickened and hard, and their refined abilities obliterated.

192. The cuticle, therefore, is thrown over these delicate organs as a shield, to protect them against violence in the exercise of their tactile powers, to moderate the otherwise too harsh contact of objects, and thus enable them to obtain a fair and correct impression of the body touched. Its structure and properties qualify it well for this purpose; being thin enough to convey the external impression to the nerves within, and yet sufficiently thick and dense to afford the necessary guard to the parts beneath it.

The protection which it gives is well shown in

cases in which it has to endure unusually severe action from the friction of hard bodies. On the soles of the feet we find the cuticle thickened in proportion to the labour imposed upon it. It is thicker also in the palms of the hands, where it is more exposed to friction. But when it is suddenly exposed to an unusual degree of rubbing, we always observe that a new action takes place in the exposed part, by which the true skin continues to be protected from injury. A few drops of fluid are exuded beneath the cuticle, by which it is raised in the form of a blister, and the pressure is taken off from the more tender surface below. This is often seen in the hands of persons who, after a long period of inactivity, in which the palms have become white and delicate, suddenly exercise themselves with the broom, or hammer, or any implement requiring much action of the hand; and blistering of the cuticle is very common in the feet of those who walk a long distance after a considerable duration of rest. This is when the pressure is partial and severe. "If it be still partial, but more gradually applied, a corn is formed. If, however, the general surface of the palms or soles be exposed to pressure, the cuticle thickens until it becomes a defence like a glove or a shoe. Now what is most to be admired in this thickening of the cuticle is, that the sense of touch is not lost, or indeed diminished, certainly not at all in proportion to the protection afforded by the thickened skin."

The utility and absolute necessity of the cuticle is strongly exemplified with those who deal in corrosive liquids, and accidentally receive them upon their hands and face. Such acids, for instance, as

sulphuric, muriatic, and nitric, may remain upon it for several seconds, affording time to be washed away, and produce no injurious effect. Without its protection, the *mildest* fluids or solids would not be endured by the sensitive true skin an instant.

Besides being the organ of the sense of touch, the skin performs other very important functions, which may be noticed under four heads.

1st, Its elasticity; 2d, Its power of transpiring; 2d, Its power of absorbing; 4th, Its sensibility.

ITS ELASTICITY.

193. The elasticity of the cuticle and the other layers of the skin is exemplified in all persons who experience a change in bulk; whether corpulent or emaciated, the skin has generally the same tension, yielding to the former condition and contracting with the latter.

This quality is more strikingly shown in diseases which are accompanied with distention of the whole or any part of the body, as dropsy or tumours. Its elasticity permits the skin to be stretched sometimes to an incredible extent, without any pain or suffering, and without any impairment of its functions.

In these cases, however, the extension of the skin is very gradual, giving it ample time to accommodate itself, by its elasticity, to the varying bulk. A different and peculiar arrangement of the skin is made in these parts when an extension is sudden and frequent, as in the bendings of the joints. Over the knuckles, elbows, knees, &c., the skin is much more loose than in other parts, and is ar-

ranged in transverse folds or ridges, which freely admit of the flexion of the joints, by which the folds are all taken out and the skin made smooth.

ITS TRANSPIRING POWER.

194. The skin performs another highly important function. It is one of the great regulators of the temperature of the body, co-operating in this with the respiration (59). It is well known that animal bodies generally, under the most variable circumstances, maintain a uniformity of temperature; examined in the torrid climate of the equator or in the icy regions of the north, it is found always, in a healthy condition, to stand at 98°. In the most variable climates, too, the same point is maintained all the year round; and it becomes, then, a very interesting inquiry to ascertain in what way this constancy of temperature is kept up.

It is a well-established fact, that there is continually exuding through the external integuments a considerable quantity of moisture, called "perspiration," which, when copious, as during exercise in warm weather, stands out in drops, but at other times ekes out more slowly in the form of a vapour, so that it cannot be perceived, and is then denominated "insensible" perspiration. Experiments have shown the latter to be thrown out, on an average, to the extent of from twenty to thirty ounces in twenty-four hours. Now if this quantity were discharged from the system all at once by any means, the effects produced by it on the temperature of the body would be totally lost; it is, therefore, by the *manner* in which it leaves the system that its beneficial results are produced.

In the animal body, the respiration, as shown in a former place (70), is the principal *producer* of the heat of the body, while the skin, by the processes of transpiration and evaporation, is its great *regulator :* in the summer preventing its rising above the natural standard by a copious flow, and in winter the exudation being so much diminished as to allow it to rise to that point.

In the summer season or in equatorial climates, when the temperature of the surrounding atmosphere is elevated to a near equality with that of the body, the transudation of this fluid through the skin increases to a great extent. Exposed to the air as it stands upon the surface, it rapidly evaporates. The process of evaporation, as every chemist knows, is a cooling process. It is employed on many occasions in the arts to effect a decrease of temperature. In the countries of the East, where the weather is always hot, there is a similar process used to cool the water for drinking; it is placed in shallow earthen vessels, and its own evaporation tends very greatly to reduce its temperature.

Every one has experienced the grateful sensation caused by a current of air, either natural or artificial, passing over the skin in the midst of the summer's heat. The temperature of the current is the same as that of the surrounding quiescent atmosphere, and the cooling effect is only to be attributed to the increased evaporation from the skin, produced by the moving air, and carrying off caloric more rapidly from the surface.

195. In the winter's cold or the northern regions, the discharge from the skin is checked; and

although it always exists in some quantity under the form just mentioned, of insensible perspiration, it is only just sufficient to keep the skin in a moist, pliant, and elastic condition. When the system is labouring under a high fever, the action of the skin is entirely stopped, producing a harsh, dry, and exceedingly disagreeable condition of this organ. It is then almost always the first object of the physician to restore the action of the cutaneous surface by appropriate medicines, knowing, as he does, that an organ so extensive has, by its peculiar function, a powerful influence over the temperature of the whole system. If he can cause an evaporation to take place from the skin, the unnatural heat of the body will soon be reduced to its proper standard.

196. From these facts may also be learned the great importance of keeping the surface of the body free from all impurities, that the pores of the skin may be kept constantly open, and the perspiration be allowed at all times to have uninterrupted egress. A clean skin is almost as necessary to good health as food is to life.*

* The regulating power of the skin over the temperature of the body may not inaptly be compared with that of the *governor* of a steam-engine. This is an instrument for regulating the speed of the engine. It is formed very much like a pair of tongs, with a heavy ball at the end of each leg, and is attached to some part of the machinery so as to revolve horizontally. If a pair of tongs are held by a string tied to the handle, and made to revolve, the legs will fly apart in proportion to the rapidity of their motion. The motion of the *governor* is precisely analogous to this. When the engine works too fast, the legs of the instrument fly wide apart, and, by an ingenious contrivance, partially close the steam-pipe so as to lessen the supply of steam, and the engine moves more slowly. If the steam gets too low, the instrument slackens its motion, the legs fall closer,

197. The influence of an elevated temperature over the quantity of fluid exuded from the skin is well known, but the statements made by physiologists of the great amount of loss sustained by those who work in a heated atmosphere would not be credited were they not verified by frequent experimental proofs. Among the latest of these are those detailed by Dr. Southwood Smith, Physician to the London Fever Hospital, who has accurately observed the effects produced upon some men employed in the immediate vicinity of very hot fires. He says, "This I was enabled to accomplish by the assistance of Mr. Monro, the manager of the Phœnix Gas Works, and of Mr. Cooper.

Experiment I.—November 18, 1836, at the Phœnix Gas Works, Bankside, London.

"Eight of the workmen regularly employed at this establishment in drawing and charging the retorts and in making up the fires, which labour they perform twice every day, commonly for the space of one hour, were accurately weighed in their clothes immediately before they began and after they had finished their work. On this occasion they continued at their work exactly three quarters of an hour. In the interval between the first and second weighing, the men were allowed to partake of no solid or liquid, nor to part with either. The day was bright and clear, with much wind. The men worked in the open air, the temperature of

and by that motion *open* the steam-pipe wider, so as to admit more steam, and thus the movement of the engine is kept at a uniform rate. Analogous to this ingenious provision is the excretory function of the skin.

which was 60° Fahr. The barometer 29° 25′ to 29° 4′.

	Weight of the men before they began their work.				Weight of the men after they had finished their work.				Loss.	
	cwt.	qr.	lbs.	oz.	cwt.	qr.	lbs.	oz.	lbs.	oz.
Michael Griffiths -	1	1	14	10	1	1	12	2	2	8
John Kenny - - -	1	0	26	10	1	0	24	1	2	9
John Ives - - -	1	0	14	2	1	0	11	8	2	10
James Finnigan -	1	1	10	6	1	1	7	0	3	6
William Hummerson	1	0	24	4	1	0	20	8	3	12
Timothy Frawley -	1	1	8	10	1	1	4	12	3	14
Patrick Nearey - -	1	1	14	10	1	1	10	8	4	2
Bryan Glynon - -	1	1	0	4	1	0	24	1	4	3

"*Experiment* II.—Nov. 25, 1826.

"Day foggy, with scarcely any wind. Temperature of the air 39° Fahr., barometer 29° 8′. On this occasion the men continued at their labour one hour and a quarter

	Before.				After.				Loss.	
	cwt.	qr.	lbs.	oz.	cwt.	qr.	lbs.	oz.	lbs.	oz.
Patric Murphy - -	1	1	0	0	1	0	27	2	0	14
John Broderick - -	1	0	9	4	1	0	8	0	1	4
Michael Macarthy -	1	0	11	9	1	0	10	3	1	6
Michael Griffiths -	1	1	15	8	1	1	13	2	2	6
James Finnigan -	1	1	12	4	1	1	9	12	2	8
Bryan Duffy - -	1	1	11	12	1	1	9	0	2	12
John Didderick -	1	1	11	5	1	1	8	8	2	13
Charles Cahell - -	1	1	4	5	1	1	1	6	2	15

"Charles Cahell, the man who on this occasion lost the most, was weighed previously to the commencement of his work, with all his clothes off, excepting his shirt, which was kept dry and put on him again when weighed a second time at the end of his work. He was then immediately put into a warm bath at 95° Fahr., and kept there half an

hour: he complained of being weak and faint, and when reweighed had gained half a pound.

"*Experiment* III.—June 4, 1837.

"Day clear, with some wind. Temperature 60° 5′.

	Before.				After.				Loss.	
	cwt.	qr.	lbs.	oz.	cwt.	qr.	lbs.	oz.	lbs.	oz.
Robert Bowers -	1	1	19	0	1	1	17	0	2	0
William Mullins -	1	1	3	0	1	1	1	0	2	0
Charles Cahell - -	1	1	2	0	1	1	0	0	2	0
John Kenny - - -	1	0	22	2	1	0	19	8	2	10
Bryan Glynon - -	1	0	27	0	1	0	24	4	2	12
John Haley - - -	1	1	4	0	1	1	1	4	2	12
Benjamin Faulkner	1	1	15	14	1	1	13	0	2	14
Michael Griffiths -	1	1	8	8	1	1	5	8	3	0
John Broderick -	1	0	4	6	0	3	27	8	4	14
John Didderick -	1	1	6	12	1	1	1	10	5	2

"The last two men worked in a very hot place for one hour and ten minutes; all the rest worked about an hour. Michael Griffiths, as soon as he had finished his work, was put into a bath at 98°, where he remained half an hour. He was reweighed on coming out of the bath, and had lost 8 oz.

"From these observations it appears that, towards the end of November, when the temperature of the external air was 39°, and the day was foggy and without wind, the greatest loss did not amount to 3 lbs. (2 lbs. 15 oz.), the least loss was 14 oz., and the average loss was 2 lbs. 3 oz.

"In the middle of the same month, when the temperature of the air was 60°, and the day was clear, with much wind, the greatest loss was 4 lbs. 3 oz., the least loss was 2 lbs. 8 oz., and the average loss was 3 lbs. 6 oz.

"In June, when the temperature of the external air was 60°, and the day exceedingly bright and clear, without much wind, the greatest loss was 5 lbs. 2 oz., the next greatest loss was 4 lbs. 14 oz., the least loss was 2 lbs., and the average loss was 2 lbs. 8 oz."

ITS ABSORBING POWER.

198. The faculty of absorption possessed by the skin is directly the reverse of that last described. By it is meant the faculty of taking up substances placed on its surface and carrying them inward.

This is done by means of little vessels called *absorbents*, which are so fine as to be scarcely visible to the naked eye, unless when inflamed or otherwise diseased.

They are particularly abundant on the extremities. One end opens upon the skin, and the other terminates in the venous circulation. The mouth of the absorbent is so exposed, that a substance placed upon the skin is taken up by it and is carried along the little vessel, probably by capillary attraction, until it reaches the vein, into which it is emptied, and thence soon enters the system through the circulation of the blood.

This is the mode in which the highly important process of vaccination is effected; a process by which multitudes of lives are now annually preserved, and one of the most horrible diseases ever experienced by man is almost exterminated from the earth. The external cuticle is raised in some part of the skin, by which the absorbent vessel is more fully exposed, and a small particle of the vaccine virus is inserted, which is soon absorbed, and

in from four to six days it exhibits the proof of its influence over the whole system.

It is in this way also that the poisonous matter from the teeth of a rabid dog finds an entrance into the system from a bite, causing the disease called hydrophobia.

Physicians sometimes employ this method of introducing medicines into the circulation, which the state of the stomach or other cause will not permit the introduction of in the usual mode. By removing a small portion of the cuticle with a blister, and placing a dose of medicine on the exposed part, it is readily absorbed and carried into the system, generally with the same effect as by the ordinary and more agreeable mode. The author once relieved a person afflicted with fever and ague by introducing into the system in this manner the common remedy, the sulphate of quinine, which the stomach of the patient was entirely unable to retain.

Persons are stated to have been fed through the skin, and kept alive for a considerable time by the absorption of nutritious substances.

ITS SENSIBILITY.

199. The great sensibility of the cutaneous covering of the body presents it to us in an extremely important and interesting point of view. The source from which its sensibility is derived, and some of its effects, have already been described, and it now remains only to show some more of its good offices. The external surface of the body is endowed with a sensibility which the deeper parts do not possess. "The extreme sensibility of the

skin to the slightest injury, conveys to every one the notion that the pain must be the more severe the deeper the wound.

"This is not the fact, nor would it accord with the beneficent design which shines out everywhere. It serves not only to give the sense of touch, but it is a guard upon the deeper parts; and as they cannot be reached except through the skin, and we must suffer pain, therefore, before they are injured, it would be superfluous to bestow sensibility upon these deeper parts. In pursuing the inquiry, we learn that when the bones, joints, and all the membranes and ligaments which cover them are exposed, they may be cut, pricked, and even burned, without the slightest pain." "Had these parts a sensibility like that of the skin, it must have remained unexercised; they would have possessed a quality which would never have been useful, since no such injuries can reach them without warning being received through the sensibility of the skin."

"Such a sensibility, therefore, would not only have been superfluous, if bestowed upon the internal parts which act in the motions of the body, but would be a source of inconvenience and continual pain in the common exercises of the frame. The mere weight of one part on another, or the motion of the joint, would have been attended with that degree of suffering which we experience in using or walking with an inflamed limb.

200. "The fact of the exquisite sensibility of the surface, in comparison with the deeper parts, being thus ascertained by daily experience, we cannot mistake the intention that the skin is made a safeguard to the delicate textures which are contained

within, by forcing us to avoid injuries; and it does afford us a more effectual defence than if our bodies were covered with the hide of a rhinoceros."

The internal parts of the body, nevertheless, have a sensibility differing entirely from that of the skin, and very appropriate to their situation and their uses.

Sprains, ruptures, and diseases excite the sensation of pain in whatever part they may occur, warning and requiring us to act accordingly, either to allow the parts to rest and recover themselves, or to apply the proper remedial measures. And it is remarkable that the degree of pain excited is generally in proportion to the extent and importance of the injury.

The sensibility to pain is, therefore, not a defect in our organization, as some would suppose, but a "benevolent provision, bestowed for the purpose of warning us to avoid such violence as would affect the functions and uses of parts."

CHAPTER X.

THE NERVOUS SYSTEM.

201. The view which has been presented in the foregoing pages of the various animal functions there treated of, has not comprised, with one exception, any consideration of the source from which they derive their peculiar powers. They have been particularly studied with reference to their mechanical and physiological endowments, their vital properties having hitherto been purposely kept out of sight, with the expectation that an avoidance of this more abstruse department would be more likely to interest the student in those operations themselves, and likewise engender a desire to learn afterward something of the means by which they are all enabled to carry on their functions with such uniformity and freedom from interruption, and also of the instrument by which this agency operates upon them.

It has been shown that it is to the inscrutable principle of *life* that the animal structure is indebted for its very existence, as well as its continuance as such ; for without it, the natural chemical affinities of matter, to which it is opposed, would resume their operation, and complete destruction ensue to the fabric.

It is this vital principle which gives to the digestive system its power of converting food into

chyme, chyme into chyle, and this into blood; to the heart and bloodvessels their power of circulating this fluid; to the lungs their power of purifying it; to the blood itself the power of imparting nourishment to the body; to the bones their power of growing; to the muscles their faculty of contracting; to the joints their elasticity and lubricity; to the eyes the faculty of seeing, to the ears of hearing, to the tongue of tasting, to the skin of feeling; to the whole body its power of renovation from injury and disease.

202. Moreover, when studying the physiology of the animal system, we find ourselves attracted to a principle which appears intimately connected with its vital existence, and, at the same time, independent of, and holding a mysterious association with, its material organization. This principle is called the *Mind* or *Soul.* Neither its essence, nor the nature of its connexion with the material frame, has ever been revealed to man, and they will, in all probability, be for ever concealed from human understanding.

It has already been explained that the vital principle pervades every fibre and drop of the animal system; all parts are imbued with it. Even the blood, though always in a fluid form, and, of course, having no stationary connexion with the solid structure, partakes largely of its influence. Experiment has amply proved this. If, then, every variety of structure participates in the endowment, the question may very naturally arise, Where is its origin, and is it not within the compass of the body?

203. The *Nervous System* is that part of the

material structure which appears to be the fountain head of this peculiar principle, and to be that through which it produces its effects upon the functions.

The more immediate connexion of the mind is believed also to be with the same part of the organization, and by means of which, as an agent, it exercises its power over the animal functions.

It is totally foreign from the design of this little work to enter upon the habitudes of the mind. This belongs to metaphysics. Our only aim is here to give an outline of the structure and agency of the nerves, and of the wonderful connexion which they hold with every other portion of our frame.

204. The Nervous System consists of four principal parts: the *Brain*, *Spinal Cord*, *Nerves*, and *Ganglia*. The first two are usually considered as the great *centres* of the nervous influence, from which the nerves all derive their origin, from which they receive their power of controlling the operations of the functions, and to which they transmit all the intelligence they collect of the condition of the organs, and of the progress of their operations.

THE BRAIN.

205. The Brain occupies the cavity of the scull, which will hereafter be shown to be admirably adapted to protect this singularly important organ from external violence. In shape and size, the brain, with its enveloping membranes, corresponds exactly to those of the cavity, fitting it snugly, so as to prevent its striking or jarring against the sides in the ordinary movements of the head. Its

texture is very soft and delicate, just firm enough, when recent, to bear cutting with a knife. The central portion of the brain is white, and the external part, to the depth of about half an inch, is of a gray or ash colour.

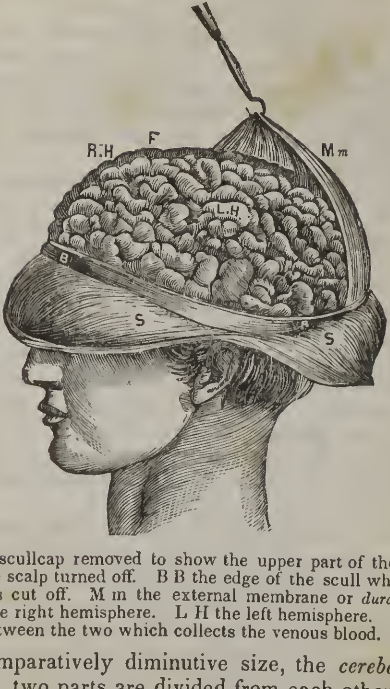
206. The first thing that is seen when the top of the scull is taken off, is a strong, smooth, and shining membrane, which adheres somewhat firmly to the bone; this membrane is the *Dura mater*.* Immediately beneath this is seen the brain, covered, however, by two other membranes, which are so fine as to permit the brain being seen through them. When these membranes† are removed, the brain itself may be touched; it presents a surface marked by a great number of undulating ridges called *convolutions*. These have fissures between them from half an inch to an inch in depth. Those who have never had an opportunity of seeing a brain may derive a pretty good idea of this appearance of its surface by observing the surface of a peach-stone; the convolutions on it present a very fair miniature representation of those of the brain.

207. It is divided into two parts, which differ very much in size, and have received names corresponding thereto. The larger part, which is placed in front, and occupies all the anterior and upper part of the cranial cavity, is called the *cerebrum*, and the other portion, which is placed at the lower back part of the cavity, is denominated, from

* Meaning *Hard mother*, from its comparative toughness.

† Called *Pia mater* (natural mother), from its embracing the organ more closely, and *Arachnoid*, from its similitude in fineness to a spider's web.

Fig. 57.



The scullcap removed to show the upper part of the brain. S S the scalp turned off. B B the edge of the scull where the cap was cut off. M m the external membrane or *dura mater*. R H the right hemisphere. L H the left hemisphere. F a fissure between the two which collects the venous blood.

its comparatively diminutive size, the *cerebellum*. These two parts are divided from each other by a strong membrane, which passes across the cavity, like a shelf, from side to side. Upon that membrane lies the back part of the cerebrum, and under it, supported by the scull itself, is the cerebellum.

This division, however, does not *entirely* sep-

arate these two parts, as they have a broad union near the centre of the base of the cavity.

There is another division of the brain into its right and left sides; this division is equal, and is made by a membranous septum running longitudinally from the forehead backward to the base of the scull behind. The two equal parts are called hemispheres.

There are a great many other divisions and subdivisions of the brain made by anatomists, chiefly for the purpose of facilitating its study, but it would be of no use whatever to give them and their names a place here. We have only to explain the general features of the nervous system.

208. The superior importance of this organ would be inferred from a circumstance which is not directly connected with its peculiar operations or influences. It has been ascertained by the anatomist, that although it has a weight of about one fortieth of that of the whole body only, yet it receives one tenth of the blood which is sent out from the heart.

209. The bones of the scull are pierced with a large number of holes, of various shapes and sizes, for the transmission of the nerves arising from the brain. The largest opening, which is, perhaps, as large as all the others together, is one of a circular shape, placed in the base of the scull, and which is occupied by the upper end of the spinal cord. The cord here enters the scull and unites with the brain. These two organs are so completely united together as to appear to be merely parts of each other, and their functions are very closely assimilated.

THE SPINAL CORD.

210. The *spinal cord*, or *marrow*, as it is sometimes, but erroneously, called, is composed of a substance exactly similar to that of the brain. It is a long column occupying the whole extent of the spinal canal, which it fills *loosely*, that it may not be compressed by the necessary bendings and twistings of this bony chain. It is enveloped by membranes similar in number and character to those of the brain; these send off detachments to each of the nerves as they proceed from the cord, in which they are closely bound up. Divisions corresponding with those of the brain may be traced through the whole length of the spinal cord, which is thus made up of four separate columns united at the centre.

The following figure presents a rear view of the Brain and Spinal Cord in connexion, exposed by the removal of the back part of the scull and vertebræ. H C, H C, the hemispheres of the cerebrum, and H c, H c, those of the cerebellum. S C, S C, S C, the spinal cord, occupying the entire length of the spinal canal, and giving off its nerves on each side, the *commencements* only of which are seen.

211. From the spinal cord a large number of nerves take their rise, which find their way out from the canal in the spine through little openings adapted to the purpose. These openings are made in a curious manner. The canal itself which contains the spinal cord is formed by the piling upon each other of the vertebræ which compose the spinal column. Each of these vertebræ forms a large ring,

Fig. 58.

which, when they are all put in place, so fit upon each other as, together, to constitute a long tube or canal. Now in the upper and lower edge of each *ring*, on each side, is a little depression or notch, made in the bone, which corresponds exactly with a similar notch made in the edges of the adjoining vertebræ, and which are adapted to each other so nicely when the vertebræ are all in place, as to produce smooth round holes for the transmission of the nerves.

THE NERVES.

212. The nerves which pass from the brain through the openings in the scull, and from the spinal cord through the openings just described, after making their exit from these parts, traverse the whole system, visiting every fibre, and giving their animating influence and protection to every function. Like most of the organs of the system, they are arranged *in pairs*, each one corresponding with its fellow of the opposite side through their central communication. There are forty-two pairs of nerves, twelve of which arise from the brain, and thirty from the spinal cord.

Those which are immediately connected with the brain supply chiefly the organs of the senses, the muscles and integuments of the head and neck, and one, as stated under the head of digestion, goes to the stomach and lungs.

The thirty pairs which arise from the spinal cord supply all the rest of the body. Of these, *eight pairs* come out from between the bones of the neck, called *Cervical* nerves.

Twelve pairs issue from between the vertebræ of the back, called *Dorsal* nerves.

Five pairs from between the vertebræ of the loins, called *Lumbar* nerves ; and,

Five pairs from openings in the lowest bone (sacrum) of the spine, called *Sacral* nerves.

The nerves themselves are small white cords or strings, varying in size from that of a man's little finger to that of a fine thread. The *extremities* of the nerves are, of course, much smaller than this, and are, indeed, so fine as to be imperceptible to the naked eye. The larger nerves are very readily traced by the knife of the anatomist. Immediately after the nerves either of the brain or spine have left their origin, they take the nearest course to their destination, except in a few instances, in which they diverge from a direct route either for the purpose of taking a more safe direction, or making a turn to supply some organ intermediate between its origin and final distribution.

213. It is a curious fact, that although the offices of the various nerves are so totally distinct, in many instances, from each other, there is no perceptible difference in their appearance or molecular structure. All are constituted of the same material precisely, a substance of a white colour and soft texture, yet possessing the most marked variations and number of endowments. Thus the nerve of vision, in physical conformation and appearance (except in shape and size, which, of course, vary with the form of the organ supplied), is perfectly similar to that of smell or hearing, or of digestion or muscular action.

214. One very important fact relating to the spi-

nal nerves is, that they are attached to the spinal cord by two heads, one head being connected with the anterior and the other with the posterior lateral column of the cord. The two roots unite so as to form one continuous nerve before they have fairly arrived outside of the spinal cavity, and no distinction can be traced by the eye or knife beyond a very short distance from their point of union. Sir Charles Bell has shown some very interesting facts connected with this double origin of these nerves. With each of its heads the nerve obtains a distinct and totally different power, which will now be explained.

215. The reader will have learned, from the remarks upon some parts of the nervous functions contained in the chapters on the hand and skin, that the sensations of the skin and other organs depend upon the nerves which supply them. In the chapter on muscular motion, it is also stated that the muscles obtain their contractile power from the same source.

But the anatomist now well knows that the same nerve supplies all these organs with their various functions, i. e., the same nerve that gives to the fingers their faculty of touch, gives also to the muscles their faculty of producing motion. Several of the upper spinal nerves coalesce to supply the upper extremity with the functions of sensation and motion, and all the innervation of the limb is derived from these spinal nerves. Now if the principal nerve of the arm be cut in two at its upper part, the limb loses both its sensibility and its motive power. This proves both to be dependant upon one and the same nerve. One nerve, there-

fore, possesses these two distinct and separate powers or functions. Long before the discovery, soon to be mentioned, made by Bell, it had been observed that a limb of any part of the body might be entirely deprived of its sensibility without its muscular strength being at all impaired; or might retain its sensibility while its muscular energies were paralyzed; but, until the time of this distinguished anatomist, no satisfactory mode of accounting for it had been adduced. He has shown conclusively that these two powers reside in different parts of the nerve; that they are obtained, one with each of its two origins, from the spinal cord, and that a distinction must exist between the two parts of the nerve throughout its entire length, though not physically apparent. He has even succeeded in showing to which of the two heads the power of giving sensation belongs, and to which that of muscular action. When he laid bare the spinal cord of a rabbit, and divided the anterior head only of a spinal nerve, he found the part which was supplied by that nerve deprived of all power of moving; it was paralyzed, but its sensibility to the pricking of a needle, &c., remained unimpaired. When, in another nerve, he divided the posterior origin, then the part supplied by it was totally insensible to pricking or even cutting of the skin, while its muscular strength was uninjured. When the connexion of a nerve with the spinal cord was entirely severed, both heads being cut off, the part lost both its sensibility and its muscular power. He thus demonstrated the double function of the spinal nerves.

216. With one exception, the nerves which

have their origin from the brain have but one point of connexion, and are capable of performing, in general, but one duty.

The exception alluded to is the *fifth* pair. This belongs to a class of nerves denominated by Bell *respiratory nerves*, because they superintend the action of the muscles of respiration. These nerves have a double operation to perform; they have to receive an impression of a want of air in the lungs, which impression must be conveyed to the brain, and they must convey from the brain, in return, the power of moving the muscles of respiration. The fifth pair constitute a part of this system, the others being derived from the spinal cord.

Like the latter, the fifth nerve has a double origin, which would, of itself, imply a similitude of function to the spinal nerves.

217. The fact that a nerve can only convey a correct perception of an impression to the brain, which is the centre of all sensation, when the impression is made upon its sentient extremity, has been before alluded to. Another curious circumstance connected with the physiology of the nervous system is that, when an impression is made upon a nerve in any part of its course between its origin and sentient extremity, the sensation excited by it is referred by the mind, not to the spot where the impression is made, but to the sentient extremity.

Thus it often happens, in many diseases, that the pain is not perceived in the part affected, but at the extremity of the nerve a considerable distance off; and people, even the sufferers themselves, will suppose the disorder to be in the place where the

pain is felt, and there apply their remedies, but unavailingly, as experience will show. Such is the case with a peculiar disease of the hip joint, in which part little or no pain is perceived, but is all referred to the knee, which may be perfectly sound.

More emphatically is this the case with a disorder which has of late years attracted great attention from both physicians and patients, called "Spinal Irritation."

It consists in a deranged condition, somewhat analogous to inflammation, of the spinal nerves at their *origin*, giving rise generally to excessive and apparently alarming pains at the sentient extremities of the nerves, while no derangement is observed at their opposite ends. The disorder is therefore referred to the organs or parts which the affected nerves supply, instead of being referred to the actual location of it; and too often, for want of the requisite knowledge and careful scrutiny on the part of the physician, remedial applications are addressed to the supposed seat of the disease, while the real locality remains undiscovered. The unhappy patient may thus have to submit to a painful, prolonged, and prostrating course of treatment without any substantial relief, while the disorder remains unabated, if not increased.

218. One of the most remarkable circumstances attending this condition of the spinal nerves, and one which renders every one more likely to be deceived as to the real nature of the disorder, is the striking similitude which it presents, by its symptoms, to actual diseases of other organs. The sensations are usually such as are experi-

enced by bona fide disorders of those organs or parts. This may be accounted for in this way. The nerve which is furnished to each organ from the spine is capable of conveying only one kind of sensation, which is suited to the wants and habits of it, the sensation of each organ corresponding to its position and requirements ; so, when the origin of the nerve becomes disordered, it can only convey the peculiar sensation which it was designed to have, thus giving rise to the very plausible supposition of a disorder in the organ itself, when it is, in reality, seated a long distance off.

So frequently does it now happen that the spinal nerves are, in this manner, either wholly or partially involved in the production of the appearances of many common diseases, that the physician is inexcusable who fails to ascertain whether the spinal cord or its nerves are or are not affected.

219. Somewhat analogous to this is the curious physiological fact often noticed by surgeons after amputation of a limb, of the patient's continuing to feel the fingers or toes as distinctly as before they were removed ; the sensation sometimes remains for several days. So clear and strong is it frequently, that the sufferer, notwithstanding the pain endured, and the assurance of the operator that it is all over, will not credit the fact of its removal without an actual inspection of the stump and severed limb with hands and eyes, and even then the sensation remains strong.

THE MUSCULAR SENSE.

220. The important discovery made by Bell, of the double nature of the nerves which give motive

power to the voluntary muscles, has been the means of making an addition to the number of our senses. The five senses of hearing, smell, sight, taste, and touch, have hitherto been considered as all that could possibly be classed under that head; but it has been left to modern science and research to claim the distinguished privilege of bringing out of the hidden recesses of nervous physiology another sense, which makes the *sixth*. The world is indebted to the able man whose name has so often been mentioned in this work, in connexion with the history of the nervous system and of the hand, for this interesting discovery, which, as far as we know, had entirely eluded the researches of preceding physiologists. There can be no doubt of the propriety of elevating this operation of the spinal nerves to the rank of the other senses, for it is emphatically a "*sense*," and one of no less importance to our welfare than any single one that can be mentioned. The truth of this will be seen in the cases which are adduced to demonstrate its existence.

The *object* of this sense is to give the individual a knowledge of the exact *condition* or *state* of his voluntary muscles. By it he knows precisely the *degree of contraction* of any of these muscles, a knowledge which he obtains independently of any other of his senses. For example, when one wishes to reach upward to grasp an object, how does he know that his arm is lying down by his side; or that it is raised a short or a greater distance; or how does he know certainly that the hand is elevated to its utmost height, when it touches nothing, neither does he see it? Through

what means is he made conscious of the extent of the muscular contractions of the arm? In fine, when the limb is in any position, either with or without contact with a foreign body, *how* does the individual know it, and, when the will desires a different position, *how* is he aware in which direction the limb must move to accomplish the desire? With one exception, and that is during the unconsciousness of sleep, it is very certain that every one is at all times cognizant of the actual condition of all his voluntary muscles, and always knows in what condition of contraction or relaxation they are. But even if he be supposed to have forgotten this condition while asleep, the instant that he wakes a perfect and certain knowledge of the position of his limbs and body exists. If he wishes to rub his eyes, he knows that his hand is by his side, and not across his chest or up in the air, and that it must be raised, and not depressed, to accomplish his object. The consciousness of the blind is, in this respect, as clear and unerring as that of him who can see, and vision, therefore, is not the source of this information.

The same knowledge, of course, must exist with respect to the position of the eyes when we wish to direct them to a different point. How does the mind perceive the actual position of the eye, or, in other words, in what way does it perceive which of its six muscles are contracted, and estimate the degree of such contraction?

The mind is distinctly impressed with not only a certain consciousness of the organ or limb, but is also perfectly aware that any particular muscle or set of muscles is in the act of contracting,

and knows how much it has contracted. The infant affords in its early efforts striking proofs of a sense of its muscular condition. "The nurse will tell us that the infant lies composed while she carries it in her arms *up* stairs, but that it is agitated in carrying it *down*. If an infant be laid upon the arms and dandled up and down, its body and limbs will be at rest while it is raised, but they will struggle and make an effort as it descends. There is here an indication of a sense, an innate feeling of danger, the influence of which we may perceive when the child first attempts to stand or run. In these its first attempts to use its muscular frame, it is directed by an apprehension which cannot, as yet, be attributed to experience."

To present this subject in a still clearer light, Sir Charles Bell (from whom the preceding paragraph is quoted) adduces another supposition of a universal case: "When a blind man, or a man with his eyes shut, stands upright, neither leaning upon nor touching aught, by what means is it that he maintains the erect position? The symmetry of his body is not the cause; the statue of the finest proportion must be soldered to its pedestal, or the wind will cast it down. How is it, then, that a man sustains the perpendicular posture, or inclines in a due degree towards the wind that blows upon him? It is obvious that he has a sense by which he knows the inclination of his body, and that he has a ready aptitude to adjust it, and to correct any deviation from the perpendicular. What sense, then, is this? for he touches nothing and sees nothing; there is no organ of sense hitherto observed that can serve him or in any degree

aid him. Is it not that sense which is exhibited so early in the infant in the fear of falling? Is it not the full *developement* of that property which was early shown in the struggle of the infant while it yet lay in the nurse's arms? It can only be by the adjustment of muscles that the limbs are stiffened, the body firmly balanced and kept erect. There is no other source of knowledge, but a *sense of the degree of exertion in his muscular frame*, by which a man may know the position of his body and limbs, while he has no point of vision to direct his efforts, or the contact of any external body."

This consciousness of the degree of action and of the adjustment of the muscles has been denominated by this ingenious author the MUSCULAR SENSE.

221. But it is not merely by inference from such cases as are cited above, nor yet by abstruse reasoning, that he comes to this interesting conclusion; he has brought his reflections to the test of practical inquiry; to observations on the animal body, the partial results of which we have already seen. The entire results are stated in the following paragraph, in his own brief but comprehensive language.

"It was this conviction, that we are sensible of the action of the muscles, which led me to the investigation of their nerves, first by anatomy, and then by experiment. I was finally enabled to show that the muscles had two classes of nerves; that, on exciting one of these, the muscle contracted; and that, on exciting the other, no action took place. The nerve which had no power was found to be a nerve of sensation; and thus it was proved that

there is a nervous circle connecting the muscles with the brain; that one nerve is not capable of transmitting what is called the nervous spirits in two different directions at one instant of time; but that, for the regulation of the muscles, there is a nerve of sensibility to convey the nervous influence from the muscles towards the sensorium, as well as a nerve of action for conveying the mandate of the will to the muscles. In their distribution through the body, the nerves which possess these two distinct powers are wrapped up, or, as it were, woven together in the same sheath; and they present to the eye the appearance of one nerve. It was only by examining the nerves at their roots, that is, where they arise from different tracts of the brain and spinal marrow, and before they have coalesced, that I succeeded in demonstrating their distinct functions. In the face, the nerve of motion passes by a circuitous course, apart from the nerve of sensation, to be distributed to the muscles; and therefore the distinct characters of these nerves were more easily proved by experiment than in any other part of the body."*

222. The double origin of the motory nerves is thus plainly demonstrated to be for the double purpose of endowing them with two distinct functions; one conveying from the brain to the muscles the power of contracting, and the other bringing back to the mind a knowledge of the contraction of the muscles. The two nerves, or, rather, the two parts of the nerve, are so intimately blended with each other as to render it utterly impossible to distinguish them except at their very commencement;

* Bell on the Hand.

yet they must be, in reality, independent of each other; for while one part is transmitting the *will* in one direction, a counter current of *sensation* is established through the other part. A single nerve could not be supposed to do both.

Nerves which are devoted to only one of these functions, as the optic, the olfactory, or the auditory nerve, which can only convey a *sensation;* or the motory nerve of the eye or of the face, which can only transmit the *will*, and give a *motory power* to the muscles to which they are distributed, have a single root or origin only, there being no requisition for a double origin, as in those nerves which perform both duties.

223. The incalculable utility and importance to us of having these nerves to perform this double function, affords another incontrovertible proof of the surpassing Benevolence which has planned the animal frame. It is very evident that the facility and instantaneousness with which we are enabled to know that our muscles are contracting when we wish it, and to estimate exactly the amount and direction of such contraction by the aid of the "muscular sense," allow us to prosecute our daily occupations without abstracting the attention of any of the other senses from their legitimate operations. This may be better understood by supposing that we were destitute of this sixth sense; that the mind had no such means of ascertaining the condition of its muscular frame; and that, in order to obtain this knowledge, which would be as necessary without this sense as with it, the creature had to employ one of the other senses, that of sight or of touch:

is it not clear that the sense, indeed both of them, would be totally absorbed in the single duty of watching over the contractions and relaxations of nearly 400 muscles and their millions of fibres? nay, could they possibly be supposed adequate to such an immense and important labour? Farther than this, there are many muscles entirely beyond the reach of either of these senses, as those upon the back, in the interior parts, deep-seated among the bones, &c. Their incompetency to furnish the mind with the requisite information is perceived at a glance; but, even supposing it otherwise, it is equally clear that their attention being entirely taken up by that work, they would be totally useless for every other purpose.

That the senses of sight and touch may be made substitutes, though in a very partial degree, for the muscular sense, and that the nerves of voluntary motion are empowered with the double function described, is shown by the following case:

"A mother, while nursing her infant, was seized with a paralysis, attended by the loss of power on one side of her body, and the loss of sensibility on the other side. The surprising and, indeed, the alarming circumstance here was, that *she could hold her child to her bosom with the arm which possessed muscular power, but only as long as she looked at the infant.* If surrounding objects withdrew her attention from the state of the arm, the flexor muscles gradually relaxed, and the child was in danger of falling. We see here, first, that there are two properties in the arm, which is shown by the loss of one and the continuance of the other; secondly, that these properties may exist through

different conditions of the nervous system; and, thirdly, we perceive how ineffectual to the exercise of the limbs is the continuance of the muscular power, without the sensibility which should accompany and direct it."

THE SYMPATHETIC NERVE.

224. Under the head of nervous apparatus, there remains to be considered what is perhaps the most singular part of the whole. It is that part by which, particularly, all the organs and functions of the system are combined, or connected together so as to have a mutual dependence, whereby their operations are regulated in such a manner as to conform exactly to each other's requirements, and all are carried on with the utmost degree of harmony and order. For example, when from any cause the action of the circulating apparatus is rendered more vigorous and active, the blood, being propelled more rapidly through the lungs, requires a more rapid decarbonization; through the medium of this nervous influence, the respiratory muscles are stimulated to increased exertion, and a greater frequency of inhalations and exhalations is the consequence. The lungs may thus be said to *sympathize* with the heart, and exert their power to relieve it. It is, however, not merely the *organic* functions which are regulated by its power, but the *mental* operations also exert an influence over the bodily functions by means of this part of the nervous system. Thus emotions of the mind, as joy, fear, sorrow, sudden fright, or shame, will instantly cause either an exalted or depressed action of the circulatory or respiratory functions, as is seen in

the flushing of the cheek, called *blushing*, or the very reverse, the blanching of the cheek with almost the pallid hue of death. Nearly every one has experienced more or less, when the feelings are suddenly excited from almost any cause, a violent palpitation of the heart, with a choking sensation in the throat, and an inability to speak, while the breathing is irregular and frequent, giving rise to violent heavings of the chest. At the same time, perhaps, the nervous system loses its command over the voluntary muscles, and uncontrolled agitation of the limbs, denominated *trembling*, is the consequence.

These instances suffice to show an intimate relation between the different functions of the animal structure, the means of which is now to be explained.

225. It is an organization of a peculiar structure, and in a great measure independent of the brain and spinal cord, though not entirely unconnected with them, as will be shown. It consists, 1st, of from 40 to 50 little knobs of nervous matter, situated in two rows, one lying on each side and in front of the spinal column, extending from the scull to the lowest point of the sacrum. Each of these is called a *Ganglion*. Hence this part of the nervous apparatus is sometimes called the "*Ganglionic System.*" Of these ganglia there are three in the neck, on each side of the vertebræ, called *Cervical;* twelve on each side of the vertebræ of the back, within the chest, called *Thoracic;* five in the loins, called *Lumbar;* and from four to six corresponding with the divisions of the sacrum, called *Sacral.* 2d, Of a single chain of bodies placed more in the centre

line of the body, and closely connected with the large organs of the chest and abdomen, whose functions they control. Each of these is denominated a *Plexus*, and is somewhat similar in character to a ganglion. One of these, the *Cardiac Plexus*, is situated in the immediate vicinity of the heart, and has especial control over its operations and those of the lungs. The second is the *Solar Plexus*, so designated from its central situation, being near the stomach, and radiating its influence in every direction, as the sun does its light. This is the largest plexus, and its influence is chiefly with the digestive organs. There are several minor plexuses connected with the different digestive organs, but they are generally considered as merely subdivisions of the great solar plexus. The third part of this nervous system is constituted of a great multiplicity of nerves, which connect all the ganglia with each other, the plexuses with each other, and the former with the latter. One set of nerves combine the ganglia into two long chains, which are united at their extremities by nervous branches, thus forming a long ellipsis. In the centre of this figure are placed the plexuses, also having numerous nerves passing from one to the other in a very intricate manner. All the various parts of this system are therefore united together in the most intimate connexion, whereby the various functions of respiration, circulation, digestion, &c., are blended into one harmonious whole. The organs over which the ganglionic system exercises its influence particularly, are chiefly those which belong to the class called "involuntary;" those whose movements and operations

are not dependent for their continuance or integrity upon the fickle and uncertain will; the muscular motions of the heart, stomach, and intestines, the actions of secretion, assimilation, nutrition, &c., being all beyond its control.

Thus far we find this part of the nervous system has an existence independent of the cerebro-spinal system, and the functions over which it presides carried on with but little immediate influence from the latter.

226. Here, also, we may trace the difference between the two classes of functions which together compose the perfect animal. On the one side we find one class of organs, which are devoted exclusively to the nourishment, growth, and perpetuity of the animal. These are under the control, principally, of the ganglionic nervous system; they are comparable to the organs of vegetable life, and are denominated the organs of *Organic Life.* The operations of this class are carried on exclusively in the interior parts of the animal frame, the organs themselves being located within the external walls of the body.

On the other side we observe a set of organs very different from these; those whose province it is to connect the animal with the external world; to enable him to receive impressions from without, and to move the various parts of his body upon each other, or the whole body from place to place at will. Vegetables have nothing in them comparable to these, and they are therefore denominated the organs of *Animal Life.* They are located principally near the surface of the body, and, in many instances, exposed to view, as those of sight,

smell, taste, the voice, and locomotion. These receive their innervation from the brain and spinal cord.

227. But, to complete the animal structure, it was, of course, necessary to unite these two classes of organs. Anatomy shows the mode in which this is done. Between various parts of these two great divisions of the nervous system there run connecting links, formed of nervous cords, which, while each part can act independently of the other, enable them to act in unison whenever occasion may require. Between each of the thoracic ganglia and of the dorsal nerves is a short nerve which forms the bond of union in that quarter; similar associations are made at the lower track of the spinal cord; connexions are also formed between some of the nerves arising from the brain and the upper part of the sympathetic nerve; but the most remarkable of all is the union formed between the brain, the lungs, and the stomach. This is by a long nerve called the Pneumogastric, a name which implies its distribution. It arises directly from the brain, and passes immediately thence, giving off no branches till it arrives at the lungs and the stomach, which it supplies with nervous energy, and thus associates in one connexion.

This anatomical fact affords an explanation of the sympathy existing between the stomach, the lungs, and the brain. This is alluded to in the chapter on Digestion, as often noticed between the former and the latter.

Frequently, too, it is found that apparent disease of the pulmonary organs, attended with pain, cough

and expectoration, has its existence almost solely in a derangement of the stomach, the effects being exhibited in the lungs, in consequence of the intimate sympathy between the two organs, through the medium of this nerve. This shows, not merely how much circumspection and cautious inquiry is necessary on the part of a physician, to enable him to arrive at a just conclusion of the nature and seat of the disorder, and, consequently, of the proper means for its relief; but it likewise exhibits to the patient a reason for not too soon giving way to despondency, in the belief of having a bona-fide disease of the lungs.

A more frequent case still—one of which almost every individual has personal experience in a greater or less degree—is that which proves the direct connexion between the stomach and head. This is pain and a sense of fulness in the head after a very full meal or error in diet, which may be transient, or which, in consequence of actual disease of the stomach, may be more permanent. The phenomenon of "sick-headache" is also a proof of this connexion: the causes of this distressing affection are various, and have their primary action sometimes at one end of the nerve and sometimes at the other. Thus improper food ofttimes gives rise to the disease, and in this case the stomach is first affected, and the head secondarily; and at other times mental emotions are the exciting cause, producing headache first, and subsequently the distressing nausea.

228. This connexion of the brain and stomach is very important and indispensable for the operations of digestion. It has been found repeatedly,

that when the pneumogastric nerve on both sides is divided, the functions of the stomach entirely cease. A very necessary influence of some kind is therefore transmitted by this nerve from the brain: the functions of the stomach do not depend solely upon the influence of the sympathetic nerve, as the ganglionic system is sometimes called.

Many other affections, which may be termed sympathetic, may be mentioned, some of which every individual has experienced; such are the general uniformity of the motions of the two eyes; the convulsive contraction of the diaphragm which produces sneezing, as caused by an irritation of the membrane lining the nostrils, which is produced sometimes also by the irritation of an intense light upon the eyes, communicated from them to the nose, and thence to the diaphragm; imperfect vision from a morbid state of the intestinal canal; vomiting from the irritation of a biliary calculus in the duct of the liver; pain in the ear from toothache; and a variety of others, the occurrence of which would never have been predicted or suspected, but which are well ascertained matters of fact.

In all these curious affections, we are well assured that the nervous system is the only immediate cause of the connexion, though it may not be possible in every instance to trace the direct conjunction by any particular nerve.

229. In connexion with this subject, it may not be considered irrelevant to allude to a sympathy which has a more extended sphere of action than the individual's own person; in which two persons are concerned, an impression being made first upon the mind, and through it upon the body. The

most familiar example which can be adduced is the action of *gaping* caused by seeing another gape.* Adam Smith, in his "Theory of Moral Sentiments," has thus illustrated this subject. "When," says this writer, "we see a stroke aimed, and just ready to fall upon the leg or arm of another person, we naturally shrink and draw back our own leg or arm; and when it does fall, we feel it in some measure, and we are hurt by it as well as the sufferer." The tendency to faint, experienced by many individuals at the sight of blood, the agitation of the heart, the irregularity and partial suspension of the respiration, pain at the pit of the stomach, or sense of constriction of the chest, &c., felt by many upon seeing or reading any absorbing scene, may be attributed to the same principle. The mental impression is transmitted to these parts by the nervous system.

* A person may sometimes create a good deal of amusement by propagating this operation through a room full of people, himself setting the example of yawning, as if unintentionally. We are told of a certain professor whose discourses were of rather a sleepy character, and whose lower jaw was very liable to dislocation when the mouth was widely distended. His students would sometimes take advantage of this defect to shorten the lecture, by yawning, and thus sympathetically act upon their tutor, and, for the time, completely arrest his faculty of speaking.

CHAPTER XI.

PROTECTIONS AFFORDED TO THE BRAIN AND SPINAL MARROW.

230. The nervous system was shown, in the preceding chapter, to be composed of four principal parts, viz., the Brain, Spinal Cord, the Nerves, and Ganglia.

The brain occupies the cavity of the scull; the spinal marrow is lodged in a long canal or tube, formed in the spine or back bone; and the nerves have their commencement in the brain and spinal marrow, and from them they traverse the entire body, carrying the nervous influence to every organ.

Various circumstances conspire to render the brain the most important organ in the body; and, when we consider its extreme liability to injury from comparatively slight causes, it will be perceived that it must require, in an especial manner, every protection against the action of everything that would have a tendency to disturb or impair its functions. We accordingly find it environed on all sides with materials and structures most wisely adapted to this great end.

There are two principal modes in which the brain may be seriously injured; the first is by an instrument being forced through its covering and entering its substance, and the second by a blow or sudden jar, either of the head or of the body, producing a concussion, or slight disarrangement or disconnexion of its parts. It seems to be with

reference to these two points principally that the protective measures have been adopted, or, at least, are most apparent.

With regard to the first kind of accident, it is to the scull alone that we are chiefly to look for protection, and we find it furnished with all the amplitude compatible with its elevated situation and its strength of material.

But to prevent concussion of the brain, we discover excellent provision, not in the scull alone, though it is here very apparent, traceable with unerring certainty of design in almost every point of the skeleton, from the apex of the head to the soles of the feet. The peculiarities of almost all parts of the bony structure, while they are made to conform with great exactness to the wants of their particular localities, seem also to have been arranged with especial reference to the grand object of giving the brain and spinal marrow, the sources of all their movements, the most ample security against any interruption of their functions from concussion.

Each of these subjects embraces very numerous and not less interesting points.

231. As the brain is the organ which contains the superintending intelligence of the human being; as it is the direct recipient of all the information obtained by the senses, whether of good or evil import; and as it holds a watchful guardianship over the whole body, it has an elevated and commanding position, that it may the more readily receive and impart every information and influence. The superiority of its duties would seem to require a corresponding altitude of situation, and its lofty

position has been assigned to it with the unquestionable view of its suffering the least disturbance from internal causes, and not so much for the purpose of placing it in that security of location which its elevated character and delicacy of structure render necessary. Notwithstanding all this, it is very doubtful whether a place could be found more free from danger than that which the brain now occupies ; its elevation removes it from dangers to which a lower situation might frequently subject it, though such a change would occasionally protect it from accidents to which it is now liable. To outweigh all supposed advantages derivable from a change from its present dangerous height to an inferior but more secure position, could such a one be found, it is only to be remembered that man is indebted for much of his present superiority over the brute creation to the commanding elevation of his stature ; to the dignity of his countenance raised above his figure ; to his lofty brow, and his quick and piercing eye ; that he is greatly indebted, too, every moment of his life, for his personal safety to the admirable situation of his senses, situated, as it were, like sentinels upon the watchtower, giving instant notice of the approach of danger, and warning to prepare against it ; all of which advantages would be greatly diminished, if not utterly lost, were his brain removed from its present altitude and placed in a more dependant position.

The principal dangers to which the brain is now exposed, are the falling of bodies from above upon the scull, and the force with which it strikes the ground when the body falls ; from both of which it would be comparatively exempt were it in a dif-

ferent position. We shall see, however, upon ex-

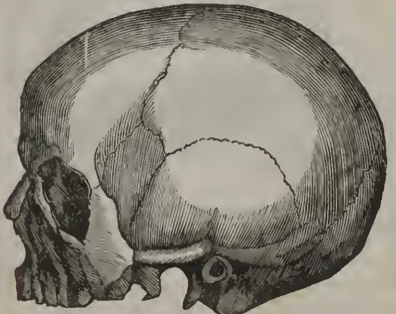
Fig. 59.

The oones of one side of the scull, detached from each other. 1, *Frontal* or forehead bone. 2, *Parietal* or wall bone. 3, *Occipital* or hindermost bone. 4, *Temporal* or temple bone; in the lower part of this is the opening of the ear. 5, *Nasal* (of the nose) bone. 6, *Malar* or cheek bone. 7, *Superior Maxillary* or upper jaw bone. 8, the *Unguis*, forming part of the orbit of the eye. 9, *Inferior Maxillary* or lower jaw bone. Between 4 and 6 is the *Sphenoid* or wedge-shaped bone. This bone runs across the base of the scull, sending a similar projection up on the other side.

amining the strong bony case in which the brain is lodged, that danger from these causes is greatly obviated by the manner in which it is made.

232. The scull is a large box or case, of a rounded form, made of several pieces of bone, firmly united together, and having its internal surface exactly adapted to the shape of the brain, which fully, but easily, occupies it.

Fig. 60.

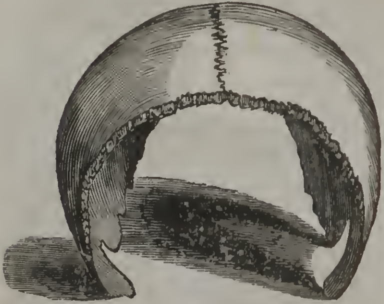


Side view of the scull, with the bones united.

When viewed at the side, as in figure 60, its shape, formed, as it is, like a dome or arch, all will admit to be the best adapted to protect its contents from the effects of pressure or a blow from above. It is very common to see people who have a heavy burden to carry poise it upon the head; an action which produces not only great pressure on the top, but likewise violent straining at the sides, or "abutments" of the arch, as they are

called in a bridge. No arch more perfect has ever been built, or abutments better arranged for sustaining pressure, than are found in the human scull.

Fig. 61.



This figure represents the two parietal or wall bones, as viewed from behind, forming an arch or surmounted dome.

By examining figure 60 it will be observed that the bones which form the arch rest upon the temple and wedge-shaped bone, all three being firmly fastened together. The latter bone gives the principal support to the arch, as it runs entirely across the base of the scull, and sends a strong branch up each side of the scull, which holds the other bones in their places, and helps very materially to support the arch.

233. We behold in this beautiful structure a piece of carpentering which the most ingenious mechanic could never expect to approach in simplicity and completeness. When a man falls so as to strike the ground with the top of his head, it is

in the temples chiefly that the scull yields; and yet the joinings of the bones are so firm that they must be fractured before they can be spurred out from each other.

"But the best illustration of the form of the head is the dome; and the human scull is, in fact, an elliptical surmounted dome, which latter term means that the dome is higher than the radius of its base. Taking this matter historically, we should presume that the dome was the most difficult piece of architecture, since the first dome erected appears to have been at Rome, in the reign of Augustus; the Pantheon, which is still entire. The dome of St. Sophia, in Constantinople, built in the time of the Emperor Justinian, fell three times during its erection; and the dome of the Cathedral of Florence stood unfinished 120 years for want of an architect. Yet we may say, in one sense, that every builder who tried it, as well as every labourer employed, had the most perfect model in his own head."*

When a person falls backward, he strikes the ground upon the *occipital* or hindermost bone. A fracture of it from this cause is in a very great degree prevented by an addition to its internal surface, which a cursory observer would probably pass unnoticed. This is what the architect calls *groining*, and consists of two broad ridges which cross the bone at right angles, giving additional thickness at those parts, and serving very greatly to strengthen it.

In a fall forward, the part of the head which first

* Library of Useful Knowledge.

strikes the ground is the frontal bone; and here, too, is an arrangement by which the danger of a fracture is in a considerable degree obviated. Immediately behind the eyebrow is a cavity in the substance of the bone, the front of which is a thick layer of bone projecting forward, which serves as an overhanging ledge to the eye, as well as a means of strengthening the forehead.

In a fall sideways, the shoulder first touches the ground, and the centre of the *parietal* bone, where it is thickest and most dense, is the part of the scull which receives the blow.

234. We have now to examine the structure of the bones themselves. They belong, as observed in another place, to the class of flat bones. Upon close inspection of all the bones of the scull (with one or two exceptions, where it is not so apparent) when separated from each other, they will be seen to be composed of two thin layers or tables, placed parallel with each other, and connected together by a cellular or spongy structure of bone occupying the space between them. The external table, which forms the outside of each bone, is uneven and rough, being marked with ridges at the places where the muscles are attached; but the internal surface, which is next the brain, is remarkably smooth and even, that its valuable contents may lie uninjured.

235. There is considerable difference in the textures of the bones of the head. Some are exceedingly light, and as thin as letter paper, as is the bone of the internal nose. Others, again, are of astonishing hardness, as that part of the temple bone which is within the scull, and contains the

organ of hearing. This is the hardest bone in the body, and partakes of the density of iron. It is called the *petrous* bone, from its similitude to a rock in hardness. This is wisely adapted to assist the hearing, a compact structure being the best conductor of sound. The two tables of the scull differ also, the internal being more brittle (hence called the vitreous), and the external of a softer and tougher nature; another benevolent provision by which their vibrations counteract each other.

236. The mode in which the bones of the scull are united together, constitutes the sixth kind of joint, as enumerated (132). It is called the suture, and can be compared to nothing in art more aptly than the carpentry by which the sides of a box or drawer are fastened together, called *dovetailing*. On examining the two scull bones in coaptation, their edges will appear to be very rough; but the projections or spiculæ of one bone are exactly fitted into the corresponding depressions of the opposite bone, and so firmly and accurately are they locked within each other, that it requires the greatest care and dexterity to separate them without breaking the little points. The union is effected entirely without aid from ligaments, as in other parts. The best mode of separating the bones of a dry scull is to fill the interior with dry peas, and then soak them with water. This causes them to swell gradually, and slowly to force the bones asunder. Notwithstanding the roughness of the edges of the bones, the surfaces of the scull are smooth at the joints, especially the internal; here there is no appearance of the suture; but the edges of the vitreous table are laid

so evenly side by side as to present to view only a smooth straight line. This is another proof of the foresight displayed in the construction of our frames; for had the spiculæ existed in this inner brittle table, as in the softer external one, they would be more liable to be broken or chipped off by the slightest vibrations, as would the edges of two pieces of glass placed together in the same way, and would produce serious injury by pressing on the brain.

237. In general, the sutures of the head are made by the edges of the bones coming square together; but there is one exception very remarkable and worthy of notice. It is that suture by which the ends of the great arch are supported upon the abutments (see fig. 61) between the wall and temple bones. The effect of a weight or blow on the top of the head is to press the sides outward. Instead of the edge of the wall-bone being placed perpendicularly upon that of the other, the edges of both are bevelled off, so that the lower bone laps over the upper on its outside, thus holding it in its place; its superior strength, before alluded to, fitting it admirably for the purpose.

238. The question very naturally arises, Why was not the scull formed of a single solid bone, which would seem to be stronger? Why are there so many bones, especially as they cannot move upon each other?

In the first place, a great reason for the existence of so many bones is to be "found among the laws which belong exclusively to the growing state; the head, in consequence of being separated into many pieces, is more readily wrought from its

form and size in the embryo state to the form and size required by adult life;" we know that the scull is not perfectly formed till many months after birth, whereby the brain has an opportunity to come to its full shape and volume, and to which the scull is gradually accommodated.

It must be also recollected, that in infancy this multiplicity of bones is one of the greatest safeguards of the brain, on account of their elasticity, and the readiness with which they yield to blows and falls, without producing any vibration of the scull or consequent jarring of the brain.

239. Let us now observe in what manner a moderate blow upon the head is prevented from producing any injury to the brain, premising that a vibration of the scull, by communicating a corresponding motion to the brain, is more dangerous ofttimes than an instrument forced through the bones and piercing the substance of the brain.

First, the hair, which is outside of all, assists to break its force by its elastic, cushion-like protection; then the soft scalp, formed partly of muscle and partly of fat and skin, acts in the same way; the scull then receives it, but its vibrations are diminished in consequence of the cellular structure connecting the two tables, and of the difference between their densities; the vibrations of the two not corresponding, they neutralize each other in a great degree. The vibrations are then still farther checked by the internal lining of the scull, which is composed of two soft membranes; these operate to prevent vibration precisely as would a coating of soft leather inside of a bell when it was struck; so that, by the time the force of the blow

has reached the brain, it has become diminished to a harmless proportion, giving strong evidence of the surpassing benevolence which has guided the wisdom which has erected our frames.

It has been well said by an eminent writer on this subject, that "these provisions would surely have met with earlier attention had men contemplated in a true view the object of the animal framework, which is not to give absolute safety against inordinate violence, but to balance the chances of life, leaving us still under the conviction that pain and injury follow violence: so that our experience of the injury and our fear of pain, while they are the principal protection of life, lay the foundation of important moral qualities in our nature."

240. Concussion of the brain, as has just been said, is generally productive of more immediately serious effects than a puncture of its substance. It is well known, in fact, that a considerable portion of it may be removed or destroyed without proving fatal, or even injuring the mental faculties; but a sudden jar of its whole substance will almost certainly deprive the individual of all sense and consciousness, and, if not speedily recovered from, must terminate in death. Even a slight concussion communicated to the brain from a jarring of the body, as in making a false step or jumping from a height, produces very painful feelings in the head, and frequently confusion of the intellect. With little accidents of this kind we daily meet, and we are now to examine the means by which the effects of these, as well as of a thousand unavoidable shocks, as in walking, running, &c., are obvi-

ated. When a person leaps or falls from a height, and strikes on the feet, a violent vibration is given to the whole frame; but the head being placed at the other extreme end of the body, by the time the concussion reaches it, its force has become so much broken and dispersed, by the various and excellent contrivances for the purpose, that the brain scarcely feels it. Commencing at the feet, we may trace arrangements for this wise purpose through the whole line of the body.

241. The human foot displays another beautiful arch, though constructed in a very different manner from the scull. It is formed more like the arch of a stone vault, as respects the shape of its materials, being composed of several bones of an irregular wedge form.

Every one, by examining his own foot, will perceive its concavity underneath, and convexity above, and that the arch rests upon the *heel* behind, and the *balls of the toes* in front. The elevation of the arch, however, is much more plainly to be seen when its skeleton is exposed, and it will then be observed how well formed it is to bear the immense burdens sometimes imposed upon it. The arch is formed, also, not in one direction only, like that of a bridge, but like that of a vault, from side to side.

Fig. 62.

Skeleton of the Foot.

The uppermost bone of the foot is that which forms with the leg the ankle joint, and is the *key-stone* of the arch. It is placed between two bones, which allow it to play up and down a little, as the pressure of the body requires.

There are, in all, thirty-six bones in the foot. This is a great number, but it is in order that there may be a great many joints; for the structure of a joint not only permits motion, but bestows elasticity, which latter quality is especially necessary in the foot. These numerous bones are bound firmly together in their arched form by strong ligaments, which possess considerable elasticity, allowing the structure to yield considerably when suddenly brought to the ground, or when having a heavy weight to sustain, and recovering their compactness when the pressure is removed.

242. The heel bone is one of the largest of the *irregular* bones in the body; it is so situated as to protrude considerably behind the arch of the foot, serving thereby the double purpose of giving a broad and firm abutment for the arch to rest upon, and a projecting lever for the attachment of the muscles of the calf.

Its internal structure is the same as that of the ends of the long bones; very cellular, combining strength and lightness. And we may here advert to another valuable property possessed by this cellular structure. Perhaps it should rather be called a *negative* quality; that by which the communication of a force from one body to another is prevented. This will be understood by an illustration. Suppose five ivory balls to be hanging against each other, suspended by threads; if the first one is withdrawn, and then allowed to fall

against the next, the force of the blow is transmitted through the whole series, and the last one is driven off to nearly as great a distance as the first fell from. The density of the ivory allows an uninterrupted passage to the force. If, then, a ball made of spongy bone is substituted for one of the ivory balls, and the first ball is impinged in the same manner against the others, the same effect will not ensue. The spongy structure is incapable of transmitting the momentum; "it is almost lost in the meanderings of the little cells, particularly if the bone be previously filled with tallow or well soaked in water, so as to bring it to a condition of elasticity resembling the living state."

It will be at once perceived how this quality of the spongy structure of bone operates to save the brain and all parts of the body from the results of shocks given to the feet in numerous ways; for it is not only the heel bone which is formed in this manner, but all the bones of the foot, the ends of all the long bones of the lower limbs, the bones of the pelvis, and all the bones of the spine, partake largely of this structure.

The numerous bones of the foot, whether of the arch or of the toes, are, therefore, made in such forms, and bound together in such a manner by ligaments and cartilage, as to combine, in perfect proportions, solidity, elasticity, and lightness.

243. "Another very obvious proof of contrivance is the junction of the foot to the bones of the leg at the ankle joint. The two bones of the leg receive the great articulating bone of the foot (fig. 62) between them. And the extremities of these bones of the leg project so as to form the outer and inner

ankle. Now when we step forward, and while the foot is raised, it *rolls* easily upon the ends of these bones, so that the toe may be directed according to the inequalities of the ground we are to tread upon; but when the foot is planted, and the body is carried forward perpendicularly over the foot, the ankle joint becomes fixed, and we have a steady base to rest upon."

244. The next point to which our attention is drawn affords another convincing proof of design. It is the manner in which the foot is brought to the ground in walking; a subject which deserves particular attention, not only as exhibiting another means of protecting the brain from the necessary exercises of the body, but also as holding up to view a too prevalent abuse in the modern education of young people, especially females. If any one will observe the walk of a person in front of him, he will see that the heel invariably comes to the ground first; that the toes are brought down afterward in a curve, and then the body is thrown forward over the foot.

Fig. 63.

This is the natural mode in which this exercise should be performed; for it is very clear that the

force of the shock with which the heel strikes the ground goes obliquely upward in the direction of the dotted line (fig. 63), so that the body and the brain do not perceive it; and the leg being afterward brought gently over, no concussion is produced. How different would the case be had the foot been so formed as to come flat down upon the ground at once; every step would then have caused a jolt, a frequent repetition of which would have produced serious injury to the delicate structure of the brain. Yet such is the method in which many modern teachers instruct their pupils to walk. They are taught to put the *toes* to the ground first; which it requires much effort to effect, and more still to avoid the unpleasant jarring occasioned by the subsequent descent of the heel.

THE LOWER EXTREMITIES.

245. Besides the admirable structure just described, we observe in other parts of the lower extremity several points which go far to assist in diminishing the effect upon the brain of the joltings of the body in its various exercises. In running and leaping, particularly, the system receives shocks of which the elastic arrangements of the foot, combined with those found between the foot and spine, especially tend to obviate the force. The spongy ends of the long bones, the elastic cartilages of the joints, and the curved form of the thigh bones, all concur to this desirable end. No farther description of these is requisite; but we must notice the important fact of the various directions assumed by the different parts of the limbs in these exercises. In leaping, for instance, the weight of the body, when it comes to the ground,

causes the whole frame to be bent up; every joint is flexed to a great degree, and this very flexion is a great means of diverging the force of the shock. If the body should reach the ground in a stiff, upright attitude, the force would be communicated through a direct line, and a severe concussion would ensue to the head; but when the joints are all flexed, each part of the limb and body carries a portion of the force of the shock in a different direction, or, as it were, scatters it into small fragments. We may therefore say, that the body, by its own momentum, saves itself from injury.

THE SPINE.

246. We come now to study one of the most surprising of the mechanical structures of the body; the most intricate, and displaying the most abundant evidences that a plan for the accomplishment of certain purposes has been devised, and an ingenuity, more profound than that of any human mind, has been concerned in its production.

The spinal column, or, as it is sometimes called, the "back bone," extends from the head to the pelvis, resting upon the hindermost part of the latter. It is composed of 24 small bones, called *vertebræ;* hence this part is technically denominated the *Vertebral Column.* The spine must be considered the *main pillar* of the body; for, although formed of so many pieces, it has a very great degree of firmness, and gives support to the head, to the ribs, and the contents of the chest; and it also affords a means of attachment to the stomach, bowels, liver, and all the contents of the abdomen. It contains, also, the spinal marrow, an organ second

in importance only to the brain. It gives also to the trunk of the body, by means of its numerous joints, its surprising flexibility; being, in fact, the pivot on which most of the rotations of the trunk are performed. These various functions place it in the first rank among the mechanical contrivances of the body. We are especially called upon to wonder that so long a chain of separate and distinct bones could be united in such a manner as to admit of very extensive motion, even to being bent nearly double, and yet to possess a degree of solidity and firmness sufficient to keep erect the heavy weight placed upon its summit and that attached to its sides.

Fig 64.

247. Two of the vertebræ, the uppermost, which give the different motions to the head, have already been described (150). The others differ in shape from either of these two, but resemble each other very much. Before describing the particular form of the individual bones, we present a view of them as united together, forming the spinal column.

Fig 64 presents a side view of the spine; and it will be observed to be curved somewhat in the form of the letter *f*. The two dotted lines show the three natural divisions of

the spine; the upper part belonging to the neck, the middle to the chest, and the lower to the loins.* This double curve is very important in many points of consideration. In the first place, the hollow part between the dotted lines is situated at the chest, and serves to increase that cavity, giving a larger space for the expansion of the lungs. Below this the spine bends forward at the loins, or "small of the back," as it is usually called. This operates to give a better support to the contents of the pelvis and abdomen. Again at the lower end, where it is united to the pelvis, the spine runs backward. This apparently unimportant point is one of great consequence, as we shall see. The spine rises a single column from its base, and alone has to support all the body above. "It stands, like a mast, broad and strong below, and tapering upward. The mast is supported by shrouds and stays; and if we sought for an analogy with these, we must fix upon the long muscles of the back, which run along the spine to sustain it. But as a mast goes by the board in a storm, we see where the spine would have been most in danger had not nature provided against it. When we start forward in walking or running, it is by the exertion of the muscles of the lower extremities, and the body follows. Did the spine stand up directly perpendicular, it would sustain a shock or jar at its base in these sudden motions. We see, therefore, the intention of the lower vertebræ being inclined forward from their foundation on the pelvis; for, by this means, the jar which might endanger the junction of the

* The distinction is well marked in fig 40 by the different appearances presented by the three classes of vertebræ.

lowest piece, is divided among the five pieces that form the curve."

The same principle of structure is also to be seen in the vertebræ of the neck. Almost every one has felt how painful it is to have the head jerked backward, by a sudden push of the body forward; and were it not for the forward curve of the spine at its upper part, operating precisely like the curve at the lower end, a dislocation or fracture of the bones would more frequently take place.

We have to observe now, that all the curves of the spine, operating together, serve to add very greatly to the safety of the brain, in the jolts and jars of the body, in a similar manner to that explained when speaking of the flexions of the lower extremities (245). The shock of a fall or a leap not being transmitted through a straight column, its force is divided at each bend.

248. But we find that the vertebral column, though very much curved in one aspect, in a different one is perfectly straight and perpendicular. Thus, when we view a person sideways, we see his body taking the form of the spine; at the top it leans forward, as seen in the projection of the head; at the shoulders it projects backward; and at the loins there is a curve forward. But when we view the back (fig 40) or front of his figure, we observe the spine to be perfectly straight, giving the necessary uprightness and gracefulness to his form.

249. Before saying anything more of the general features of the spine, we must become acquainted with the form and make of its several component parts.

Fig 65.

Fig 65 is a representation of one of the vertebræ of the loins. The larger part is the body, and the middle of the five projections is the spinous process, which projects backward, and can be felt under the skin, as can those of all the vertebræ, especially those at the upper part of the back. The four other projections, as well as this, are for the purpose of attaching strong muscles, and for fastening the vertebræ to each other. The *bodies* of these bones are about an inch thick, made of light, spongy bone, but very strong, and the spinal column is formed by 24 of these bones, piled upon each other like the stone blocks of a pillar supporting a roof. The vertebræ in different parts of the column are not precisely like each other; but there is no *essential* difference, except with the uppermost two already described (150).

Between the body in front and the processes behind in fig. 65 will be seen a triangular opening. When the vertebræ are all in their places in the column, these openings are all directly in a line, and form a long bony *canal* or *tube*, well protected from external injury. This is the channel in which is lodged the *spinal cord*. The tube is a little larger than its contents, so that the latter is not liable to pressure in the varied and extensive

bendings and twistings of the spine. Between each two of the vertebræ, when in their places, is a little hole on each side, formed by a notch in the side of each bone. Through this notch, the *nerves* arising from the spinal marrow are transmitted to almost all parts of the body and limbs.

250. Not the least important point in this singular mechanism is the substance which is placed between each two of these vertebræ (fig. 64), and which operates for the double purpose of granting them the greatest possible extent of motion and of cementing them firmly together. This inter-vertebral substance partakes of the nature of ligament and cartilage combined, is of a highly elastic character, and, being situated between the *bodies* of the bones, to which it is closely adherent, it serves as a strong bond of union between them. At the lower part of the back it is about half an inch thick, but not so thick at the upper part. In point of elasticity it is not inferior to caoutchouc or common India rubber. It will suffer considerable diminution of size under pressure, but will readily restore itself to its former condition when the pressure is removed. It is this substance which, constituting nearly one third of the whole length of the spine, gives this important range of bones its wonderful flexibility, so great, indeed, as to enable many persons who practise feats of strength and dexterity to bend the head backward against their heels, in which position the spine is nearly in the form of the letter U inverted.

In consequence of its compressibility, the heavy burdens borne by many people for a whole day, and even the weight of the body when kept a long

time in the erect posture, will have the effect of shortening the spine an inch or more; but when the body is recumbent for a short period, these elastic substances react and lengthen the column again. Those, therefore, who stand much during the day, are perceptibly shorter at night than when they rise in the morning.

251. But one of the most valuable results derived from the position of these elastic bodies is the security which they afford to the brain. They complete the list of contrivances so admirably arranged for this end. Nicely balanced upon the top of this curved, elastic column, the head is beyond the reach of concussion from any common cause; the inter-vertebral cartilages, assisted by the spongy structure of the bones which they unite, act in precisely the same relation to the head as do the *springs* to the body of a carriage. The wheels, rattling over the stony ground, produce a constant jarring, but by the interposition of elastic springs, which receive and retain the shock, the vehicle glides smoothly along. The spinal cartilages, in the same manner, in the various exercises of the body, receive whatever jolting is not destroyed by the other structures described, and thus give the finishing stroke to the preservatives of the house of the mind.

The vertebræ, besides being united with each other by this elastic substance, are also *jointed* together by apparatus constructed on the same principles as the moveable joints heretofore described. These joints are small, and consist of two flat surfaces laid against each other, one looking upward and the other downward. They are

faced with cartilages, have synovial membranes and capsular ligaments. Although the spine, as a whole, has a very extensive motion, either in bending or rotating, these little joints, which are the parts upon which the motions of the spine are made, have, *individually*, very little of it, but their great number compensates for the deficiency. As both faces of the joint are flat, the motion produced between them is a *twisting* or *sliding* of one face upon the other; hence they constitute the joint which has been enumerated as the *fifth kind* in a previous chapter (132).

It is evident that a small degree of motion only is admissible between any two vertebræ, in consequence of the danger which would otherwise result to the spinal cord, which they are all intimately concerned in protecting from injury. But by the ingenious contrivance exhibited in this multiplicity of bones, every requisite facility and extent is given to the flexions of the body.

252. We have thus seen a most striking example of the harmony which pervades the organization and operations of the animal frame. While the nervous system lends its incessant aid to carry on the functions of the body, sending strength, animation, sensibility, and vigour to every molecule of its structure; while it imparts to it that inscrutable principle by which it is enabled to resist successfully the attacks of destructive agencies within and without; while it posts its ever-watchful sentinels over the myriads of fibres, of a thousand diversified kinds, affording them secure protection while in repose, and exciting them to activity while at work, giving to every part an instant warning of

the approach of danger, and carrying to the fountain head, with the quickness of thought, the notice of any departure from purity of action in any of the agencies of its widely-extended empire; while, in a word, it keeps in action every function, however important and however inconsiderable, of the body, the latter, as if grateful for all this expenditure of power and protection, and in return for the multiplied and continued exertions of kindness, recompenses the obligation by lavishing unsparingly upon it the most ample means of security against the encroachments of accident, and of preservation from exposure or decay.

CHAPTER XII.

THE "PACKING" OF THE BODY.

253. In a machine so very complex, and whose moveable parts are so numerous and closely applied to each other as are those of the animal body, there must necessarily be a great amount of friction produced, which, without a counteracting influence, would greatly impede the movements of the various parts as they rub upon the adjoining structures, and subject them to a wearing process, which would greatly obstruct their usefulness and power. When describing the joints, the apparatus designed expressly to lubricate these organs and prevent their friction was described at length (137), as pe-

culiarly adapted to those parts. The synovial fluid was shown to be exuded upon the inner surface of a sac which lined the faces of all the bones forming the joint, and thus was prevented from escaping from the joint.

But the joints form a very small portion of the parts in or upon which friction is produced. The great masses of muscles which lie upon each other, and the numerous tendons passing from them in nearly parallel lines, and closely bound together, present strong views of the extent in which friction is generated by the motion of these organs upon each other. A very slight examination of the manner in which the numerous tendons of the wrist, for example, pass in a small space under the ligament which binds them down to their places, the close contiguity existing between them, and the extent of motion among them when one or more are moved by their respective muscles, will convince any one that, unless some means were adopted to prevent friction between them, not only impediment to the movements, but great wear of the surfaces, both of the muscles and tendons, must result.

They are made to occupy the smallest possible compass, that all clumsiness may be avoided in the formation of the body and the limbs, while this very contraction of space serves to increase the friction.

If we inspect the situation of all the tissues of the frame, we find all more or less subjected to friction; bones, muscles, tendons, ligaments, nerves, bloodvessels, skin, and cartilage, are each in some degree exposed to it.

The means of obviating this, which would otherwise be a source of endless trouble, pain, and suffering in every part of the body, will form the subject of this chapter.

The desired end is obtained in a mode which displays, in a marked manner, one of the characteristics of exalted inventive genius, i. e., *simplicity of means* combined with *perfection of attainment.*

254. Friction is obviated between the parts which rub upon each other, in all places except those before described, by the intervention between them of a substance of a peculiar nature denominated *cellular tissue.*

This consists of a very fine and delicate membrane, without colour, and so arranged upon itself as to constitute an endless number of little cells, whence it has derived its name. The cellular construction of this tissue is not perceptible as it is ordinarily presented to view when in contact with other parts. But if a portion of it be raised, and a blowpipe be inserted into any part of it, when air is forced into it, the cells which were before empty and compressed into a small compass now become inflated and distended, and are made more distinct. The cells are made by the crossing and recrossing of portions of the membrane upon other portions, and, when distended, present various and irregular shapes, but generally of a cubical form.

A good conception of this arrangement may be formed by calling to mind the peculiar formation of the honeycomb; supposing it to be formed of a very soft, delicate, and semitransparent membrane, instead of its dense, opaque, and waxy material,

but with the cells arranged in a somewhat similar manner, though with more complexity and irregularity. If this honeycomb structure be then supposed to be compressed very closely, so that the sides of the cells shall be all brought into contact with each other, a good idea of the cellular tissue, in its natural form, may be had.

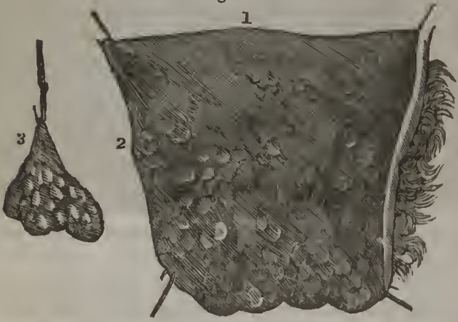
Fig. 66.

A portion of the CellularMembrane distended, showing its reticular structure.

Thus constituted, this curious tissue intervenes as a separating medium between all these moveable parts, and it is this which receives the friction; to sustain which it is well adapted, by, 1st, Its peculiar formation. Admitting, as it does, of considerable distention when inflated, it will readily be perceived that, when void and compressed, it will be loose and moveable upon itself, and will give little or no impediment to the movements of the adjacent parts to which it is attached. 2d, By its being kept always in a soft, moist, and, conse-

quently, a pliant condition. It is this tissue which is the nidus of that peculiar unctuous part of the animal body called *fat;* and as the cellular structure is always more or less furnished with this oily matter, it is in this respect well fitted to be the medium of motion between adjacent parts. In a healthy condition of the body, the cells of this structure always contain the fat, to which purpose they are particularly appropriated, having thus two objects, which, in a most admirable manner, are made to assist each other.

Fig. 67.



1, a portion of Adipose or Fatty Tissue beneath the skin. 2, minute Bags containing the Fat. 3, a cluster of the Bags separated and suspended.

255. There is still another purpose to which the cellular tissue is appropriated. It will strike the observer, that, in the construction of the body, made up, as it is, of parts of a rounded form, vacant spaces must frequently occur at the ends and sides of the different organs. This is particularly the

case in the limbs, where the muscles are large, of great number, and, in consequence of their various shapes, cannot be applied to each other so that no vacancy shall occur between them. And yet it will be just as apparent that no vacuity could be allowed to exist, for various reasons, but especially because the pressure of the air upon the surface of the body would cause deep and unseemly depressions, and interfere in some degree with the movements of the muscles. On the external surface of the body particularly, the muscles, by their variety of forms and positions, cause very deep and irregular cavities in many places, which would destroy much of the uniformity and evenness of outline now presented by the body, were these furrows not filled up, as they are, by some other substance.

The cellular structure just described is the "*packing*" which is used to fill up these intermediate spaces, both in the interior of the limbs and other parts, and also those at the surface. When employed for this purpose, this tissue is more copiously supplied with fat, so that, in fact, it is this latter which occupies the bulk of these spaces; but this being of an oleaginous consistence, and more nearly approaching the fluid form, the cellular structure is necessary to keep it in its place. The cells are more or less distended with the fat, which, being thus divided into a great number of small parts, is prevented from being permanently compacted by pressure, and enabled to retain its *elasticity*, a highly important quality of this substance.

The cellular tissue and the fat are both very abundant outside of the muscles of the body and

limbs, and between them and the skin. Particularly does it abound in all corpulent persons, the increased size of the body in such being attributable almost solely to a superabundance of this material, while the amount of muscle and bone may be no greater than usual.

Its utility in this situation is made very apparent when we call to mind the looseness and mobility of the whole cutaneous surface of the body, observable especially on the back of the hand, where the skin may be pinched up to a great extent. If drawn aside by this means or by any of the necessary movements of the muscles or joints, the skin, by its elasticity, aided by that of the cellular tissue, which connects it with the parts beneath, returns to its proper position when the strain upon it is released.

256. The looseness, distensibility, and cellular arrangement of this tissue, are demonstrable in two diseases, of which it is the principal seat. The first of these is a species of dropsy, denominated *anasarca*, in which the cells become infiltrated and distended with serum effused from the veins, which pass and repass through them. That these cells are all communicable with each is evinced by the circumstance of the water finding its way, in obedience to the law of gravity, from the upper to the lowermost parts of the body; those who are troubled with this disorder in a moderate degree, perceive this in the swellings of the feet and legs, which are there greater at night after an upright position through the day, and always diminished in the morning after the horizontal position of the night. During sleep in this posture, the fluid dis-

perses itself through all parts of the limbs, and is thus made less apparent in the feet, to which it returns again during the day. When the foot or any other part is distended from this cause, the pressure of a finger will cause a depression or "pitting," deep in proportion to the force applied, which will remain for several minutes after the pressure has been removed. The reason is obvious; by the pressure the cells immediately beneath the finger are emptied of their fluid, and the hollow remains a while because the fluid can return but slowly into them from the surrounding parts, in consequence of the intricate structure.

The other disease alluded to is of a surgical nature. It sometimes happens, when a rib is fractured, that the adjacent cellular tissue under the skin is opened by a point of the bone; and at the same time the lung is lacerated from the same cause, whereby air is admitted *through* the latter into the cavity of the chest, and thence finds its way into the cellular tissue, between the skin and ribs. By the actions of the chest in breathing, considerable quantity of air is forced into this tissue, which for a greater or less extent, becomes inflated and distends the skin.

It is a practice among veterinary surgeons, in some disorders to which the joints of the horse are liable, to make an opening in the skin near the affected part, introduce a small tube, and with the aid of a pair of bellows to force air into this cellular structure and distend the skin; the effect of this operation is to take off the pressure of the surrounding parts from the diseased part, and so to give it relief.

CHAPTER XIII.

DIGESTIVE APPARATUS.

257. THE inquiry which, next to the study of the wonderful properties and powers of the circulating fluid, will most naturally attract our attention, is the source from which it derives its ability to continue its functions, and from which its own wastes are supplied. We have seen that the blood is subject to a constant loss of its healthy properties; an incessant draught is made upon its pure particles, and impure matter is as constantly added to it. The function of Respiration, as explained in a former chapter, is one of the principal means of the *purification* of the blood, to which the skin and the kidneys lend a powerful aid; but we must look to another quarter for the source of those *additions* to the blood of new and healthy matter, without which it would soon become exhausted.

A separate apparatus, occupying as great an extent of space as any other function, and involving a greater complexity of parts, is devoted to this important purpose.

258. Commencing at the lips, in the function of digestion (by which term is meant the *process of converting the aliment into blood*), the apparatus consists, in the first place, of *the Teeth*, which serve the purpose of grinding and cutting the food; 2d, the *Œsophagus* or *Gullet*, a long tube down

which the food descends; 3d, the *Stomach*, a membranous bag which receives the aliment from the œsophagus, and in which is performed the first important change in its condition; 4th, the *Duodenum*, or *second Stomach*, a small bag in which the materials undergo a still farther change; 5th, a long convoluted tube, *the Intestines*, over the inner surface of which are scattered the mouths of numerous small vessels, called, 6th, the *Lacteals*, whose office it is to absorb so much of the digested food as is qualified to enter into the formation of the blood, and, with a remarkable discrimination, rejecting that which is unsuitable; these lacteals gradually unite with each other until they form, 7th, one tube, the *Thoracic Duct*, into which they all pour their contents; which duct or canal soon discharges itself into one of the large veins near the heart, whence its contents find their way into the general circulation, becoming part and parcel of the vivifying blood. This enumeration is merely of the organs concerned in the *transmission* of the nutrimental food from the mouth to the heart; the auxiliary organs, whose assistance is necessary to the changes of the material, and the nature of those changes, as far as we can understand them, will require a separate consideration. In close proximity to the mouth are situated several glands, the two principal of which have been described (82) as placed just under and behind the ears. The office of these glands is to secrete a peculiar fluid, called *saliva*, which is carried into the mouth through little tubes or ducts. These glands are so situated that the working of the jaw in chewing compresses them, and forces the fluid along to mix

with the food (fig 26), softening and preparing it for the action of the stomach.

259. The teeth are thirty-two in number in the natural adult state, sixteen being in each jaw. They are divided into four classes, the division being founded on their varieties of shape and office. Fig 68 represents the number and form of the teeth in each half of each jaw, the sides corresponding exactly with each other, and those in the upper with those in the lower jaw. Being

Fig. 68.

1 and 2, Incisors or cutting teeth. 3, Cuspid or tearing tooth. 4 and 5, Bicuspids, having two points in the crown. 6, 7, and 8, Molares or Grinders.

thus masticated and softened, the food is carried backward by the muscles of the mouth and tongue, and thrown into the top of the œsophagus, down

which it descends into the stomach. This tube is situated directly behind the windpipe, and between it and the spine.

260. The action of swallowing, that by which the food which enters into the mouth finds its way into the stomach, is not entirely a passive operation, even after the muscles of the mouth have carried the food back to the top of the long tube or œsophagus. It is not by the mere force of gravity that the food descends into the tube: it is aided in its passage downward by the action of the muscles of the tube itself. This any one can prove by throwing the body over a chair or table, and allowing the upper half to hang to the floor, and then drinking a glass of water. It will find its way to the stomach as readily as in the upright position, yet contrary to the force of gravity. In long-necked animals, when drinking from a pool or trough, this fact is clearly demonstrated. In them, also, as the horse and cow, the action of the food-pipe in swallowing may be distinctly seen. The muscular fibres which assist in the action of deglutition are in two sets, one arranged in *circles* around the tube, which, when they contract, diminish its diameter; and the other *longitudinal*, which, by contracting, shorten the tube. The circular fibres being of great number and distinct from

Fig. 69.

Œsophagus; a b, section showing the interior circular fibres, c, the external longitudinal fibres.

each other, they contract one after the other, beginning at the upper end immediately after the food has fairly entered, and thus propel it onward, in which action the longitudinal fibres greatly assist.

261. We have now arrived at the organ which has excited perhaps more curiosity, produced more speculation and theory than any other in the body. The most careless observer must sometimes have noticed the intimate connexion existing between the stomach and almost every other part of the animal frame; how readily it sympathizes with other organs, and how often the physician is obliged to address his remedy to distant parts, for the purpose of alleviating an apparent disorder of the stomach. Vomiting is often produced by a blow on the head, and even death is sometimes caused by a stroke on the stomach. The sympathy between the *mind* and gastric organ is likewise very remarkable and well known, "as often, upon the reception of distressing intelligence, the stomach ejects its contents or refuses to receive more." It has often been noticed how completely excitement of the youthful mind will take the place of habitual hunger; and Shakspeare well knew the effect of mental agitation on the stomach, when he put into the mouth of one of his characters the language,

> "Read o'er this, and after this,
> And then to breakfast with what appetite
> You may."

There is thus clearly demonstrated a very close connexion between this organ and the centre of life, wherever that may be. But the anatomist can

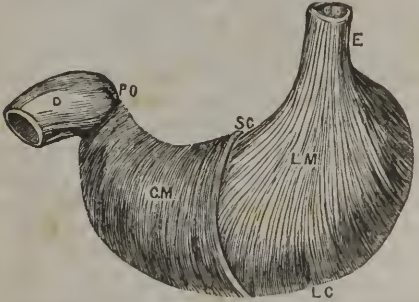
show through what means this connexion is maintained; he will point out the numerous delicate cords which unite the more vital organs with this, which, in turn, supplies them indirectly with the material of their formation. It is now well known that the stomach is more liberally supplied with nerves than any other organ in the body; that through the medium of these nerves it is connected with a greater number of organs than any other, and that these nerves "are remarkable for the variety of sources from which they are derived." The nervous system is arranged, as explained in a previous chapter, in several general divisions; and, in general, the various organs of the system are supplied with but one kind of nervous influence. The case is, however, entirely different with the stomach. Its nervous influence is derived from all the sources at once, not only those which are situated nearer to it, but it is more remarkably "distinguished from all other parts of the body, except what are termed the organs of sense, by having a pair of cerebral* nerves almost entirely devoted to it, although it is situated at so great a distance from the brain:" and it is abundantly supplied from each of these sources. Partaking thus largely of these united attributes, "the stomach appears to possess, in a very high degree, many of the powers which are ascribed to the nervous influence; it is exquisitely sensitive, while it partakes remarkably of the general actions of the system, sympathizing with all its changes, so that it may be regarded as a kind of common centre, by

* Belonging to, or derived from, the *brain.*

which the organic functions are connected together and their motions regulated." Shall we wonder, then, that before a more rational mode of thinking and investigation was adopted by philosophers, Van Helmont and others believed this organ to be the seat of the immortal soul, and claimed for it powers which belong alone to that invisible and intangible part of our nature?

262. The stomach is an irregular oval bag, lying across the upper part of the abdomen, immediately

Fig. 70.



The stomach divested of its serous covering, to exhibit its muscular coats. L M, the longitudinal muscular fibres; C M, the circular fibres; E, the lower end of the œsophagus, entering its larger extremity; D, commencement of the duodenum, joining its smaller extremity; C O, the cardiac* orifice; P O, the pyloric† orifice; S C, the smaller curvature; L C, the larger curvature.

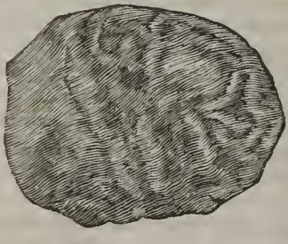
behind what all know as the "pit of the stomach." Its structure is composed of three principal membranes: viz., the external or *serous coat*,

* Meaning nearest the heart.
† Signifying a guarded entrance.

which is dense and elastic, serving as a covering to the organ, which it has in common with all the viscera of this region. Next to this lies the *muscular coat*, which is composed of numerous muscular fibres, running in three directions; one set going longitudinally or lengthwise with the organ, and the second transversely, encircling the viscus in its smaller circumference, and the third running obliquely with the others.

Within the muscular tunic, and forming the inner lining of the organ under consideration, lies the most delicate and important of all, the *mucous coat*. The texture of this tunic is very fine and soft, closely resembling silk-velvet; its colour is generally, in a healthy state, a cloudy white, though very often it has a pink hue, from the multitude of fine vessels with which it is furnished. When examined with a microscope, the surface of this coat is observed to be studded with innumerable small orifices, not more than 6-100 part of an inch in di-

Fig. 71.



A portion of the inner surface of the stomach, showing the folds formed by the mucous coat, and the velvety appearance it assumes.

ameter, which are the openings of tubes leading from small glands situated within the structure of the membrane, and which pour in a mucous fluid, which serves to soften the membrane. In the undistended state of the stomach this coat is thrown into numerous irregular folds or wrinkles, which, as the membrane is not elastic, allow a considerable distention of the stomach without injury. The stomach, when moderately distended, will hold, in the adult, about three pints.

263. Besides the mucilaginous fluid just spoken of, elaborated to lubricate the inner surface of the mucous membranes in general, this coat in the stomach is furnished with a similar apparatus devoted to the secretion of another fluid, of the utmost importance in the process of digestion, and possessing the most astonishing powers. This is the *gastric juice*. It is this peculiar fluid, which is ever present in the stomach, and ready at any moment to act upon whatever food may come in contact with it, operating by its silent but irresistible power upon animal and vegetable with like facility, and completing the first important step in the digestive routine.

264. These three membranes are connected with each other by a reticulated structure between them, called cellular membrane, which holds them closely together. That portion which lies between the muscular and mucous coats serves also as a bed for the transmission of the nerves and blood-vessels, and has been denominated, though incorrectly, the nervous coat. The stomach has two circular openings, one by which it receives the food from the œsophagus, called the cardia, from its greater proximity to the heart, and the other,

through which the partially digested mass is expelled when in a fit condition to be acted upon in the next organ by other fluids.

265. As before hinted, this organ is more abundantly supplied with nerves than any other in the body, which is the reason of its extreme sensibility, and the great influence it has, directly, over other parts of the system. Not only is it profusely invested with the nervous influence common to all the animal organs, by which its life and vigour are sustained, but it is no less distinguished for the abundance of that species of it denominated the *sympathetic* nervous influence (224), by which its sympathetic union with the other parts of the system is maintained, and which is the cause of those phenomena witnessed in this viscus when injury or disease affects a distant organ. This lavish expenditure of nervous energy is only equalled by the extent to which it is supplied with blood. The arteries which supply the stomach are not only exceedingly numerous, but, in order to accommodate themselves to the different degrees of its distention, and, consequently, the extension, of the surface over which they run, they are observed, when the organ is empty and flaccid, to be very tortuous in their course. This serpentine direction of the arteries, it is supposed, serves also the purpose of checking the impetus of the current of blood, which might otherwise, on occasions of sudden excitement of the stomach, be thrown upon it with such force as to injure it. The bloodvessels and nerves, after winding their way through the more external coverings, both emerge upon the inner surface of the innermost or mucous coat, where

they terminate by exceedingly minute capillary ramifications, each sending twigs to each of the multitude of glandular openings just noticed. The system of venous vessels is, of course, of corresponding number and shape with the arterial.

266. Passing from the stomach, we come next to another bag of smaller dimensions, but, in general, of the same construction, differing only in some particulars relative to the part which it has to perform in the operation of digestion. This is sometimes termed the second stomach, technically the *duodenum.* It is composed of a like number of coats with the stomach, having the same appellations and similar offices, except the mucous, which, as it furnishes no fluid similar to the gastric juice, has a different function allotted to it. It is the organ in which the aliment, after being acted upon by the stomach, comes in contact with the bile and other fluids, which produce another marked change in its nature. The duodenum, in strict anatomical language, cannot be said to be any other than the commencement of that long tube called the small intestines, as it is nearly of the same size and directly continuous with it; though, *physiologically* speaking, it may be considered as a distinct organ, for the operation carried on within it is essentially different from that of the remainder of the digestive canal.

267. The opening between the duodenum and the stomach, through which the aliment passes from the latter into the former, is termed the *pylorus*, and is peculiar in more than one respect The muscular fibres are here concentrated into a strong band, encircling the opening, which has the

power, by contracting, of completely closing it, and of enlarging it by relaxation. It thus controls the exit of the contents of the stomach; and being endowed with uncommon sensibility, it has a singular discriminating power in allowing such parts only of the material in the stomach to leave it as are sufficiently prepared for farther action, and rejecting that which is to be farther acted on in the stomach. The peculiar office and functions of the pylorus form one of those subjects that were considered by the older anatomists as something singularly wonderful or mysterious. The delicate sensibility of the stomach was conceived to reside chiefly in this part, and it was also thought to produce some specific effect in the process of digestion, which could only be explained by supposing it to be endowed with extraordinary powers and qualities. It was this spot that "Van Helmont conceived to be the peculiar seat of the soul."

268. We will here terminate for the present our anatomical dissections, and return to the stomach, to take a view of the operation which it is its peculiar office to perform.

If we begin to review the theories which have been framed to account for it, from the very commencement, when anatomy and physiology first burst the fetters in which superstition had bound them, and stood forth to claim their just rank among the sciences, we shall find some of the most fanciful vagaries that have ever been produced upon any subject. The process of digestion has been a most prolific source of imaginative speculation, and, though simple, as it apparently is, has given rise to as much philosophical disputation as any other

function. It may not be uninteresting to take a glance at a few of the more prominent hypotheses which have in succession occupied the attention of physiologists at different periods, before proceeding to state what is now believed about it.

First came the theory of Hippocrates, which was adopted by Galen and the ancients generally, which supposed the change was produced in the aliment by what is termed "*concoction*," a term derived from the change observed to take place in substances when they are exposed to a certain degree of temperature in close vessels. By this theory, one would suppose that its authors were ignorant of the existence of the gastric liquor, which is rendered the more probable, as their dissections were confined to the lower order of animals, where it is not so likely to be noticed.

The next hypothesis was that of *putrefaction*, an hypothesis which was maintained by some of the earliest chemists, and was supported by various observations and experiments that were supposed to be favourable to it. The food, when it is received into the stomach, was observed to have its texture broken down, and to have acquired an unpleasant odour, which the older physiologists, according to the loose method of reasoning which they employed, regarded as a species of putrefaction. It is a sufficient refutation of this hypothesis to remark, that digestion and putrefaction are processes of a totally different nature; and that, so far from their having any connexion with each other, one of the first effects of the gastric juce is to resist putrefaction, or even to suspend it if it has actually commenced. "The fact appears to be, that it is decidedly antisceptic."

Next came the doctrines of the Mechanical Physiologists. To give a view of their notions, it will be necessary to premise, that there are certain animals possessing stomachs of very great muscular power, generally called gizzards, in which the food received into them undergoes a very powerful compression, and is ground down almost as in a mill, and thus fitted for the next step in the digestive process. The gizzard supplies the place of teeth in those animals. With the shortsightedness common to all who frame theories and then cause facts to bend to them, the mechanical physiologists extended to all classes of animals an action which belongs to certain species only, and attempted to prove that the muscular coat of the human stomach is placed there to triturate and mash the food within it, and mechanically to reduce its consistency to a soft mass. "Physiological speculation," says a late writer, "was perhaps never carried to a greater excess than by Pitcairne, in the estimate he makes of the mechanical force which the stomach exercises in digestion. After employing much learned and abstruse discussion to prove that no other power is competent to produce the requisite effect upon the aliment, he calculates that the power of the muscular fibres of the stomach is equal to 12,951 lbs." He does not tell us what becomes of that delicate, velvety, and exceedingly sensitive internal lining of the stomach under this pressure of nearly eight tons to which it must necessarily be subjected. Had this man not left behind him something else to prove his claim to rationality, we should be inclined to believe, with Van Helmont, that *his* wits, at least,

were in his stomach, and had been ground by this enormous gastric press into a nonentity.

"In opposition to the mechanical doctrine of trituration, an opinion was advanced by the earlier chemists, that the action of the stomach consisted of a species of *fermentation*."

This hypothesis, in the sense in which the term fermentation appears to have been understood by them, "met with more credit than any of its predecessors, and seemed to explain the process upon more rational and scientific grounds." They employed the term fermentation to express any change which a body experiences, either by the action of its constituents upon each other, or by the addition of a foreign substance, in consequence of which the elements of the body are made to enter into new combinations." "The correctness of this hypothesis must depend upon the exact sense in which the term is employed (there being several kinds of fermentation); for it must be admitted, that, according to the mode in which it was used by the older writers, the change produced upon the aliment by the stomach appears to fulfil all the conditions that were supposed to be requisite to fermentation."

Of still more modern date is the theory of *chemical solution*, which is considerably analogous to that of fermentation. This supposed the action of the gastric juice to be similar to that of a chemical solvent, and it appears to come still nearer the truth, according to the experiments performed; but still this hypothesis is also encumbered with serious difficulties. It explains but one part of the process of digestion, that performed in the stomach,

and even in this does not satisfactorily account for matter of the same composition being invariably produced from all kinds of ingesta by a solvent apparently so little active as gastric juice.

These objections, and the difficulty of accounting for digestion upon mechanical or chemical principles, were the means, together with some new observations which were made, of the formation of still another theory, the principal feature of which was, that the function of digestion was to be ascribed to the direct agency of the *vital principle;* a principle which is entirely invisible and silent in its operation, whose presence in the living body appears to be the only cause preventing its decomposition, and of sustaining many other important operations. The interior coat of the stomach is said to be endowed with a specific property, unlike any other that exists in nature, which belongs to it as a living substance, and which enables it to digest its food.

"In proof of this position, the curious fact is adduced, which was observed by Hunter, that, in some cases of sudden death, the stomach itself is partially digested by the gastric juice which had been previously secreted" having lost the protection of the vital principle, which before death prevented the action of the fluid upon the organ itself. Frequently, too, worms have been found in the stomach, whose vitality has rendered the gastric juice harmless to themselves, though after they have died it affects them as it does any other organized substance. These facts are curious and important, and clearly prove a difference in the mechanical and chemical relations of living and

dead matter. This doctrine of the *animists*, as they are called, "proceeds upon the principle that no modification of the laws of mechanics or chemistry can account for the phenomena, and it is consequently necessary to meet the emergency by the assumption of the existence of some new agency." By this procedure, however, we throw no new light upon the difficulty, and only employ a different expression to announce the fact.

"Somewhat allied to the hypothesis of the animists, although much less vague and indeterminate, is the doctrine which has lately been advanced, that digestion is essentially a *nervous* function, or one that depends upon the immediate and direct agency of the nervous system." The variety and number of the nerves with which the stomach is provided, and a number of well-known occurrences, which prove that the powers of the stomach are intimately connected with the nervous system, certainly go far to sustain this supposition; but what was thought to prove conclusively its correctness, was the fact that, when in a living animal the principal nerves of the stomach were divided, so as entirely to cut off its communication with the nervous centre, the process of digestion was arrested, and ceased to go on. But, in strict reasoning, this and other similar experiments go no farther than to prove the agency of the nervous influence in preparing the gastric juice; for the presence of this fluid is essential to digestion, whatever other powers may be requisite; and the dividing or cutting the nerves, by arresting its formation, puts a stop to the process of digestion.

We have now taken a *coup d'œil* of the various

theories which have, from time to time, been broached to account for this most interesting and curious operation, no one of which appears alone to satisfy the mind. It is a great satisfaction to feel that the present advanced state of chemical science has enabled the physiologist to refute these exclusive dogmas, and put the stamp of improbability, at least, upon many of their pretensions. We look now to a combination of causes for the effects of digestion, and we believe that chemical, mechanical, and vital forces have each a share in this complicated operation, believing, with the celebrated Hunter, that the function of digestion is a peculiar one; that its nature is not to be likened to that of any other known operation; and that, to use his own expressive language, "to account for digestion some have made the stomach a mill; some would have it to be a stewing-pot, and some a brewing-trough; yet, all the while, one would have thought that it must have been very evident that the stomach was neither a mill, nor a stewing-pot, nor a brewing-trough, nor anything but a *stomach*."

269. We will now trace the operation through its successive steps, and explain, as intelligibly as the nature of the case will admit, the changes produced at each turn. The food, after the operation of mastication and swallowing, comes in contact with the stomach, in which is secreted the remarkable fluid called the Gastric Juice. The chemical action of this liquor, and the mechanical operation of the muscular coat of the stomach, produce a change in the course of a few hours upon the food, by which it is converted from a heterogeneous

mixture of materials into a mass of pulpy matter, scarcely resembling its origin in any respect, even the odour of it being altered. The precise nature of this operation of the gastric juice it is very difficult to determine, though it is now generally believed that the fluid is endowed with some chemical solvent powers, which, although unlike those of any other substance, and apparently very simple, are capable of exerting a change in the chemical composition of the food. The gastric liquor acts only upon the food where it touches it; and, consequently, were it to lie still in the stomach, a very long time would be required for it to operate upon the whole mass; to obviate this difficulty, the muscular coat is continually in action; its fibres contract and relax one after another, and thus the aliment becomes rolled and tumbled about, a new surface being constantly presented for the action of the fluid. This operation may be likened to that of churning. The combined effect of these two causes is to change the structure of the mass of food, to dissever its parts from each other, and to convert it into a mass entirely different in appearance and consistence. The result of this operation is what is called *chyme*, by which term is understood a soft, pultaceous mass, of a peculiar odour. All alimentary substances are alike reduced to this condition by the powerful action of the gastric juice, which, simple and apparently inert as chemical analysis shows it to be, has the power to dissolve even hard bones, while the soft skins of fruits and the fine fibres of flax or cotton are not in the smallest degree affected by it. These operations, bearing so close a resemblance to the

changes of chemical affinity, have enabled the physiologist to determine very nearly the nature of the action, though it is difficult to conceive how such complete chemical and mechanical changes can be wrought by a substance to all appearance so very inert as is the gastric juice.

270. This solution of the alimentary matters in this juice being now completed, the chymified mass is presented to the pyloric orifice for admittance into the duodenum. We have alluded to the discriminating tact of this part of the stomach, whose singular sensibility enables it to detect in the matter presented to it any part which may not be sufficiently prepared by the first organ to undergo the subsequent operations, and which is sent back to be still farther dissolved. There are some cases, however, in which positively indigestible substances have been passed, such as buttons, coins, knives, &c. When these bodies are brought to the pyloric orifice they are rejected, and the rejection is repeated until the sensibility of the part is overcome by the frequent and long-continued contact of them, and the opening becomes, as it were, wearied out with their importunities, and they are at last allowed to pass.

271. The well formed chyme now enters the duodenum ; and here another important and material change is made upon it, its chemical composition being still farther altered. The agents employed in this operation are, as in the first case, liquids, assisted by the vermicular action of the organ. These liquids are the bile, the pancreatic juice, and, it is supposed, a fluid secreted by the duodenum itself.

272. The *Liver* is the organ devoted to the formation of the bile. This organ is a large gland, situated on the right side under the ribs, where it is suspended by ligaments.

Fig. 72.

A view of the abdominal digestive organs. S s, the stomacn. D the duodenum. S I, the small intestines. L I, L I, the large intestines. R the rectum. L the liver. G B the gall-bladder, the two communicating with the duodenum by a duct. P the pancreas. S the spleen.

"The food is forced on its way from the stomach by what is called the *peristaltic* or *vermicular* motion of the bowel, one circle

of fibres narrowing after another so as to propel its contents slowly but steadily, and resembling in some degree the contractions of a common worm."

The liver is the largest gland in the body, from which circumstance alone its importance would be readily inferred. It is very freely supplied with blood, and secretes a large quantity of its peculiar fluid, which is transmitted to the duodenum through a tube called the *Biliary Duct.*

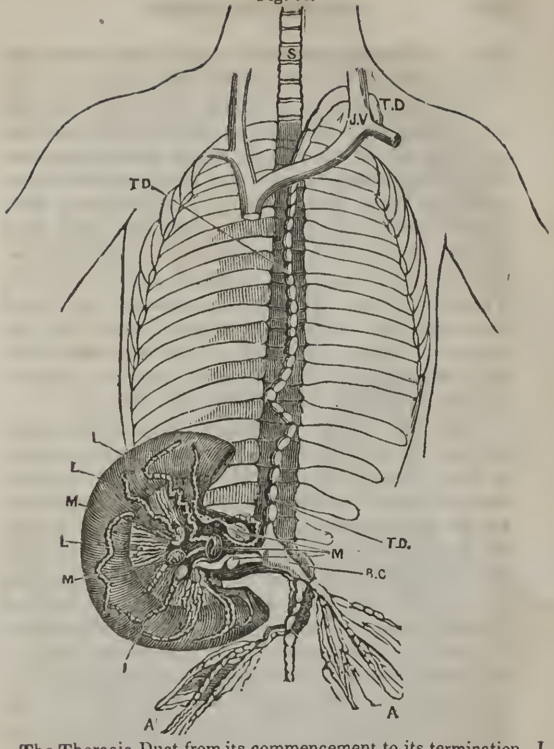
The *Gall-bladder* is a membranous bag, capable of containing two or three ounces, attached to the under side of the liver, and communicating with the biliary duct by a short tube (fig. 72). It serves as a reservoir of bile, being kept well supplied by the liver, and a sufficient quantity is thus always at hand to act upon any amount of chyme admitted into the duodenum, without its having to wait for the action of the liver.

The pancreatic juice is derived from the *Pancreas*, commonly called the "Sweetbread," another gland situated behind the stomach, and connected with the duodenum by a tube, through which its fluid flows. This fluid is very similar in constitution to the saliva of the mouth, and the organ is reckoned among the salivary glands.

273. These two fluids appear to have the chief agency in operating upon the chyme from the stomach, and converting it into what is termed *chyle.* The nature of this operation is enveloped in some obscurity, and it has been disputed whether these fluids, and particularly the bile, serve to assimilate the different parts of the chyme and to mix it up more completely, or whether their office

is to separate its ingredients from each other, and to act upon such as are suitable, to render them more fit for still farther use. Be this as it may, we soon find the digested mass changed in its colour, composition, and consistency; the chyle, properly speaking, which is to go to add to the blood, is of a white, opaque appearance, considerably resembling cream in its aspect and physical properties. It becomes gradually separated, as it passes along, from the residual, inert part of the mass, until it has advanced so far as to come in contact with the orifice of the little lacteal tubes which are to convey it towards the heart. Here we observe another instance of sensibility amounting almost to intelligence, and one of the most beautiful provisions of nature for the preservation of the body from contamination with substances incompatible with its healthy condition, although presented at its very threshold. The mouths of these vessels are endowed, like the pyloric orifice of the stomach, with a faculty which they exercise for the preservation of the animal. Not only are they gifted with a capability of taking up the material destined to the nourishment of the body, but likewise with a discriminating power, by which they are enabled to reject that which would prove injurious to it. Thus, although a mass of matter, composed of the most discordant materials, some highly nutritive and beneficial, others of an eminently deleterious nature, intimately mixed, is presented to the mouths of these vessels, they select the good from the bad, and, while the latter is rejected and carried away, the former is taken up by

Fig. 73.



The Thoracic Duct from its commencement to its termination. L L L, Lacteal Vessels, taking their rise from a section of the Small Intestines. M M, Glands of the Mesentery, in which the chyle undergoes some change as it passes through them to R C, Receptacle of the Chyle from the Lacteals. T D, T D, Thoracic Duct, ascending along the Spine, S, and emptying into the Jugular Vein, J V, at its junction with the vein from the left arm. A A are the Trunks of the Absorbent Vessels coming from different parts of the body, and discharging their contents into R C.

them, and moves onward to supply the wastes and deficiencies of the "wear and tear" of life.

274. The *lacteals*, so called from their contents resembling milk, are very numerous, their mouths studding the mucous coat of the small intestines with little protuberances; as they advance, they gradually unite with each other, lessening their number, but enlarging their diameters, until they are all found emptying themselves into one tube, which, from its situation in the chest, is called the *Thoracic Duct*. This tube conducts the liquid chyle upward to the point where it is to join the current of blood. It empties itself into one of the large veins just as it is about to pour its contents into the right side of the heart (fig. 73).

275. The power by which the lacteal vessels take up the chyle from the intestines, and by which it flows through them and through the thoracic duct, is that of capillary attraction. These vessels act as capillary tubes. In this absorbent action, the fluid is not impelled forward by any force like that of the heart or arteries, but it is assisted along by the mode and place in which the thoracic duct discharges its contents into the general circulation. By referring back to the description of the mechanical arrangement of the veins of the body (40, 41, 42), the point now about to be elucidated will be better understood. It was there shown, that the manner in which the veins are joined together facilitates the progress of the blood through them.

When two tubes unite to form one large tube, the one entering the other nearly at a right angle, as do the veins, if a hole be made at the angle of union, no fluid will escape, but air will be drawn in.

This is, therefore, a point of negative pressure, or, rather, a point with a pressure inward. If another smaller tube is inserted at this angle, the contents of this tube will be drawn forward in like manner; at least no impediment to its progress will exist there. This is the principle by which the thoracic duct, the trunk of the absorbent system, is enabled to discharge its contents.

Fig. 74.

T D is the thoracic duct, V v the great jugular vein descending from the head, and V the great vein coming from the arm.

These veins join at an angle, and the streams from them leave a point between them, where there is no pressure. Therefore the fluid from T D meets with no obstruction from, and is rather *drawn in* by, the currents in V v and V.

For a moment the beautiful cream-coloured chyle presents a strong contrast to the dark fluid with which it is soon mingled; the stream, as it is poured into the vein, apparently struggles to avoid the contamination, and endeavours to support itself

above the turbid liquid; but the onward rush of the circulating tide ingulfs it in its bosom, and in an instant more it is mixed with the life-sustaining current, even as the pure refreshing brook of the mountain is lost in the briny waters of the ocean.

---

276. There are no subjects in which mankind are more personally and universally interested than the condition of their digestive organs, the digestibility of the different articles of food, and the adaptation of particular kinds to each iddividual case. The power of the stomach to convert certain articles of aliment into chyme, the quality of the chyme and chyle, and, consequently, of the blood; the effects of various kinds of blood on the structures and functions of the system, and its influence upon health, have for years been prolific themes for discussions and disputations. It is doubtful whether a single subject can be named, connected with the animal economy, which has more frequently given rise to excitement, and division into parties, both among professionalists and non-professionalists, than that of digestion in its various bearings.

It would require no inconsiderable volume merely to enumerate and state the grounds of the differences of opinion which have had birth at various periods respecting the property of this food or that, whether an exclusive animal or vegetable, or a mixed diet, is the most proper to man, and a hundred other departments of the subject. It would be useless to enter into this subject in this place, and we shall content ourselves with giving as clear

a view as practicable, in our circumscribed limits, of the general principles of human digestion.

277. A great many philosophers have made the function of digestion the subject of a number of experiments, with the view of ascertaining the effects of the gastric juice upon various substances, and of the difference of time, &c., which it requires completely to dissolve them, with the nature of the chyme, and other equally important points. These experiments have for the most part necessarily been made on inferior animals; for the results required could, of course, only be arrived at by destroying their lives. Dogs have chiefly been employed. Besides the impossibility of seeing in these the actual progress of the operation, there was always more or less doubt thrown over the propriety of the deductions made from the results observed, on account of the possibility of death, at the moment of its access, producing some change in the nature of the gastric and other juices, or in the digestible matter, &c.; and, on the fair supposition that a difference, and, perhaps, an important one, exists between the powers of the stomach and other organs of digestion of man and the inferior animals. It is well known that the stomachs of carnivorous animals are capable of digesting bones, tendons, and other matters, which the human stomach is wholly inadequate to effect.

278. Fortunately for science and truth, the insurmountable difficulties in the way of satisfactory and just inferences and conclusions, from such a course of examination, have of late years been removed by a singular and interesting accident. In the year 1822, a Canadian, named Alexis St.

Martin, received a gunshot wound in the left side which perforated the stomach. He fell under the care of Dr. Beaumont, a surgeon of the United States' Army, under whose treatment the wound gradually healed, but in such a manner as to leave open the aperture which had been made, so that there now exists below the left breast a clear opening, through which the interior of the stomach can be distinctly seen. Through it, also, substances may be introduced into this organ, and the effects of the gastric juice upon them, from the commencement of digestion to the formation of complete chyme, readily observed.

So interesting and singular a case, in an individual of good constitution and robust health, had never before occurred.* It fell into good hands, and a numerous train of observations and experiments have been made, by which many of the vexed questions connected with digestion have been settled as satisfactorily as could be desired.

In the publication by which Dr. Beaumont has given the results of his observations to the world, he has gone into very numerous details. The general results, which he has imbodied in a table and

* An analogous instance, in many particulars, occurred under the observation of the distinguished physiologist Richerand, in a woman, in whom a somewhat similar opening into the stomach was made by an ulceration. She was, however, a patient in the "Hospital de la Charité" in Paris; was in bad health; unable to retain her food until it was entirely digested, being obliged by an irresistible desire to remove the lint and compresses with which she covered the fistulous opening, and give vent to the food which her stomach might happen to contain. Very little of it passed through the pyloric orifice, though she had a voracious appetite, eating as much as three women of her age. At the time of her death she had had this opening nine years.

a series of aphorisms, are all that can be allowed room for in this work, a circumstance the less to be regretted by the reader, as his book is now of very easy access, and as his conclusions quoted below are very ample.

Inferences from Dr. Beaumont's Experiments on Digestion.

"1. That *hunger* is the effect of *distention* of the vessels that secrete the gastric juice.

2. That the process of *mastication*, *insalivation*, and *deglutition*, in an abstract point of view, do not in any way affect the digestion of food; or, in other words, when food is introduced directly into the stomach, in a finely divided state, without these previous steps, it is as readily and as perfectly digested as when they have been taken.

3. That *saliva* does not possess the properties of an alimentary solvent.

4. That the *first* stage of digestion is effected in the stomach.

5. That the *inner coat* of the stomach is of a pale *pink* colour, varying in its hues according to its full or empty state.

6. That in health it is constantly sheathed with a *mucous* coat.

7. That the natural *temperature* of the stomach is 100° Fahrenheit.

8. That the temperature is *not elevated* by the ingestion of food.

9. That *exercise elevates* the temperature; and that *sleep* or *rest*, in a recumbent position, *depresses* it.

10. That stimulating *condiments* are injurious to the healthy stomach.

11. That the use of *ardent spirits always* produces diseases of the stomach, if persevered in.

12. That the appearance of the interior of the stomach, *in disease*, is essentially different from that of its *healthy* state.

13. That the *agent* of chymification is the *gastric juice.*

14. That the pure gastric juice is fluid, *clear*, and *transparent*, without *odour*, a little salt, and perceptibly *acid*.

15. That it contains free *muriatic acid* and some other active *chemical* principles.

16. That it is never found *free* in the gastric cavity; but is always excited to discharge itself by the introduction of *food* or other irritants.

17. That it is secreted from vessels distinct from the mucous follicles.

18. That it is seldom obtained pure, but is generally mixed with mucus, and sometimes with saliva. When pure it is capable of being kept for months, perhaps for years.

19. That it *coagulates* albumen, and afterward *dissolves* the *coagulæ*.

20. That it *checks* the progress of putrefaction.

21. That it acts as a *solvent* of food, and alters its properties.

22. That, like other chemical agents, it *commences* its action on food as soon as it comes in *contact* with it.

23. That it is capable of *combining* with it a certain and fixed *quantity* of food, and, when more aliment is presented for its action than it will dis-

solve, disturbance of the stomach, or 'indigestion' will ensue.

24. That its action is facilitated by the *warmth* and *motions* of the stomach.

25. That it is *invariably* the *same substance*, modified only by *admixture* with other fluids.

26. That it becomes intimately *mixed* and *blended* with the ingesta in the stomach, by the motion of that organ.

27. That *no other* fluid produces the same effect on food that gastric juice does; and that it is the *only solvent* of *aliment*.

28. That *gentle exercise* facilitates the digestion of food.

29. That *bile* is not ordinarily found *in the stomach*, and is *not* commonly *necessary* for the digestion of food; but

30. That, when *oily* food has been used, bile assists in digestion.

31. That the action of the stomach and its fluids are the same on *all kinds* of diet.

32. That the *time* required for the digestion of food is various, depending upon the quantity and quality of the food, state of the stomach, &c.; but that the time ordinarily required for the disposal of a moderate meal of the fibrous parts of meat, with bread, &c., is from three to three and a half hours.

33. That the *digestibility* of aliment does not depend upon the *quantity* of nutrient principles that it contains.

34. That the susceptibility of digestion does not, however, depend altogether upon *natural* or *chemical* distinctions.

35. That *bulk*, as well as *nutriment*, is necessary to the articles of diet.

36. That digestion is facilitated by *minuteness of division* and *tenderness* of *fibre*, and retarded by opposite qualities.

37. That *solid* food, of a certain texture, is easier of digestion than *fluid*.

38. That *animal* and *farinaceous* aliments are more easy of digestion than *vegetable*.

39. That *oily* food is difficult of digestion, though it contains a large proportion of the nutrient principles.

40. That the quantity of food generally taken is more than the wants of the system require; and that such excess, if persevered in, generally produces not only functional aberration, but disease of the coats of the stomach.

41. That the *ultimate principles* of aliment are always the same, from whatever food they may be obtained.

42. That *chyme* is *homogeneous*, but variable in its *colour* and *consistence*.

43. That towards the *latter stages* of chymification, it becomes more *acid* and *stimulating*, and passes more rapidly from the stomach.

44. That *water*, *ardent spirits*, and most other *fluids*, are not affected by the gastric juice, but pass from the stomach soon after they have been received.

45. That the motions of the stomach produce a constant *churning* of its contents, and *admixture* of food and gastric juice.

46. That these motions are in two directions, *transversely* and *longitudinally*.

47. That the expulsion of *chyme* is assisted by a *transverse band*, &c.

48. That *chyle* is formed in the duodenum and small intestines, by the action of *bile* and *pancreatic juice* on the chyme.

49. That crude *chyle* is a *semi-transparent whey-coloured* fluid.

50. That it is farther changed by the action of the *lacteals* and *mesenteric glands*. This is only an *inference* from the other facts. It has not been the subject of experiment.

With regard to the *facts* recorded above, there can be no hesitation or doubt in giving them entire credence. The free and ample opportunities for experimenting afforded to their author, and the liberal manner in which he invited the assistance and scrutiny of the profession and others, entitle them to unrestrained reception. But his *inferences* may be disputed. The first is the most questionable; for it is more probable that a peculiar state of the nerves, rather than turgidity or distention of the vessels, produces the sense of hunger.

279. The individual on whom these experiments were performed being in all respects healthy and sound, his powers of digestion may be very fairly employed as a criterion to guide us in estimating the digestibility of the various articles of diet in common use.

The following extracts from Dr. Beaumont's table of, and observations on, the digestibility of different aliments, are therefore presented, as affording the most certain information to be obtained on the subject.

The articles most susceptible of digestion are of the *fish kind*. As exceptions to these, however, must be mentioned the lobster, crab, and other testaceæ.

Turkeys and geese are next in order of digestibility, while chickens are much lower in the scale.

Next to these come oysters and beef; then mutton; next veal; and, finally, the most difficult of digestion was pork, sausages, &c.

"Oily substances are digested with great difficulty, and the fat of all meats is converted into oil in the stomach before it is digested," which may in some measure account for the difficult digestibility of pork.

"Vegetables are generally slower of digestion than meats and farinaceous substances, though they sometimes pass out of the stomach before them in an undigested state;" and the tables present a striking difference between the *time* required for complete chymification of the common vegetables and several kinds of meat. Thus potatoes, beets, carrots, turnips, and parsnips, required from two hours thirty minutes to three hours forty-five minutes to become chymified, while tripe, pig's feet, venison, and salmon trout, required only from one hour to one hour thirty minutes. Fresh beef, mutton, and even, in some instances, pork and veal, were digested as readily as potatoes, or cabbage boiled.

280. Let the ingesta, however, be of whatever character, one fact, which is taught by reason and common sense, was fully established by direct experiment in the investigations of Beaumont, viz., that the time for chymification required by every

article of solid food bears a very close relation to the degree of its mechanical division, before submitted to the action of the stomach. Conjoined with this, as an important requisite, is tenderness of fibre.

In illustration of these considerations, it is well known that some substances, which, when well masticated, are very easily digested, will, when taken into the stomach in lumps, remain there a long time, and frequently produce pain and disease. If they cannot pass through the pylorus, distress in the stomach itself is the result, and an inverted action, by which the offending matter is rejected. If it gets into the bowels, increased action is there induced, indicated by colic or cramp, until a purgative movement removes the offending cause. Respecting ordinary articles of diet, this is particularly the case with the potato, a vegetable which, when well boiled, so as to be dry and mealy, or when finely comminuted by the teeth, is as readily digested as almost any other of the same class; but which, when swallowed in lumps, is productive of all the uneasy feelings resulting from the presence of a foreign body in the primæ viæ. This is proportionally the case with all articles of food.

The degree of tenderness of fibre also regulates the digestibility of materials to a considerable extent. As a general rule, therefore, we find the most delicately constructed meats and vegetables more easily digested, but the natural tenderness may be very much impaired by various artificial processes.

Salt meats, in consequence of the greater density

and toughness of their fibre, doubtless remain longer in the stomach undigested than the same kind of meat taken fresh. Dr. Beaumont found that fresh, lean, rare beef was digested in from three hours to three hours thirty minutes, and hard salted beef in four hours fifteen minutes. The mode of cooking, also, he found to influence digestibility in some degree. On the whole, we may gather from his experiments that boiled food is less readily acted upon by the gastric juice than the same kind cooked in any other way. In most instances, however, the difference is of very little moment.

In the case of cabbage it is very striking; when eaten raw with vinegar, this vegetable required only two hours to digest; but, when boiled, four hours thirty minutes. Boiled cabbage is generally and justly deemed improper food.

281. If we look for a reason for the variations thus exhibited in the operations of the gastric juice in the formation of chyme, we shall find it principally in the fact that this fluid can act only upon the *surface* of a body with which it is in contact. It dissolves the food in the manner of a chemical agent, altering the nature of the body in the part where it touches, and produces a *coating* of the new compound, which must be removed before the solvent can affect the adjacent parts of the mass. The muscular motions of the stomach affect this removal, and thus a fresh portion of the digestible body is exposed to the action of the stomachic liquor. If the food, therefore, exists in a large, condensed mass, the removal of the outer layer of digested matter must, of necessity, be more diffi-

cult and less complete than if finely divided, and a time, longer in proportion to the size of the mass, is requisite for its digestion. But if the mass be of too great a size, its complete digestion is impracticable, and the results before enumerated ensue.

Hence we may see the benefit to be derived from an attention to the first step in the process of digestion, viz., mastication. A fine division of the food, whether by the teeth or the knife, is an item of no little importance in the promotion of the operations of the stomach; it in fact presents an increased surface of the food to the action of the fluid, by which means the digestion proceeds more rapidly, easily, and effectually; and the greater the density and toughness of the fibre of the food, the more complete should be its mastication and insalivation, to soften and prepare it for the more advanced stages of the process.

CHAPTER XIV.

THE SENSES.

282. The means of the connexion established between the two great departments of the animal being, viz., the *organic* and the *animal*, have been detailed, cursorily, in paragraphs 226 and 227. We have shown these two to be independent of each other so far as the actual operation of the

functions of each is concerned; but that, to constitute a complete animal, a necessary connexion and dependence of each upon the other is established, and that they must operate in conjunction in order to maintain the integrity and continuance of the *machine* for any indefinite length of time. Thus, when the stomach is supplied with food, the process of digestion will go on unaided by, and entirely independent of, the muscles of locomotion, or any other of the functions of animal life.

In like manner, the circulation of the blood will continue irrespective of any of the operations of animal life, and, during the hours of waking and sleeping, this fluid continues to flow, though a more direct and close connexion is established between this function and those of animal life.

So, likewise, the animal functions are capable of operating, for a time, without *direct* assistance from the organic functions; e. g., the voluntary muscles may contract, the fingers may exercise the faculty of touch, or the tongue that of taste, while the stomach is quiescent, and the heart is pulsating without unusual excitement.

283. But it is evident that neither of these classes of functions can continue long in vigour and health without assistance from the other. If the heart withholds its blood, or the stomach refuses to perform its duty, death to the animal is sooner or later the inevitable result; while, if paralysis attacks the animal functions, the supply of food must be cut off from the stomach, for want of which the whole machine must in time cease its operations, and dissolution ensue.

Each of these classes of functions has, there-

fore, a dependence upon the other, which, though somewhat remote, is absolutely essential to the well-being and prolongation of the life of each. Each supplies the other with the necessary pabulum for its sustenance, and if both are maintained in integrity, a state of healthy activity ensues to the individual.

The progress of the operations of the organic functions has been traced, step by step, from the reception of the food into the stomach until its distribution, in the form of living blood, through every section of the frame.

284. The nature and powers of many of the organs of animal life have also been described; but a review of the modes in which they contribute to the sustenance of the organic functions will assist us in obtaining a knowledge of the proper relations held by the subjects of this chapter to the science of physiology.

1st. By the power they give to the individual to move from place to place in search of food. The vegetable, which is fixed in the ground, and derives its nourishment from the contiguous soil, without the power of going abroad to seek for food, will die unless the earth around is moistened by rain or cultivated by artificial means. The functions of the plant depend solely upon organic life. 2d. By the power they afford of reaching after, grasping, and conveying to the mouth, and thence to the stomach, food to be digested.

285. These faculties, possessed by all animals in greater or lesser degree, would, however, be inadequate to the preservation and prolongation of the individual's life, were they unaided by other and still

higher powers; in fact, their exercise would not unfrequently be the direct cause of injury and death, if the animal were not gifted with a power of discriminating between food which would be proper and that which would be improper for its use. We find, then, that there are superadded to the animal organization more noble attributes than those which merely enable the animal to move from place to place. In the brute creation, this ability to discriminate between good and evil articles of food is called *instinct;* and it is wonderful to see how perfectly it shields the creature from continually surrounding dangers in respect to its diet.

In the human animal, the discriminating faculty is of a more elevated grade, corresponding with his higher duties and greater responsibility. It is denominated *reason*, and has for its correlatives *memory* and *experience.*

286. But neither instinct, nor reason, nor the locomotive powers, nor all combined, would be sufficient to guard the animal creation from danger in selecting its food, much less would they be adequate to procure for it a supply sufficient for all its wants. Without a guide to its steps, its locomotive powers would continually endanger its safety, which its mental faculties, without assistance, could not ensure it. In short, the creature would be imperfect in its physical formation, unable to protect itself against constantly impending evils, confined to a very limited sphere of action—if it could live at all anything more than a mere vegetable life—and, at least, would be deprived of an immense proportion of the pleasures and comforts which it is now capable of enjoying.

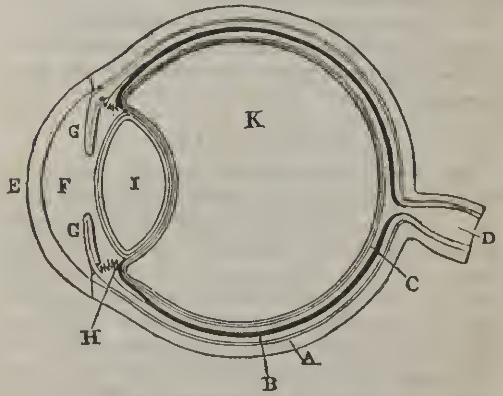
The sources of these enjoyments, and the means of preservation alluded to, are the *senses*, consisting of the faculties of *sight*, *hearing*, *tasting*, *smelling*, and *touch*.*

The organ of the last of these has already been described in the chapter on "The Hand."

THE EYE.

287. The eye is composed chiefly of *membranes* and *humours*, so arranged with regard to each other as to form a globe, which is usually called the ball of

Fig. 75.



Plan of the Eye seen in section.

A. The Sclerotic Coat.
B. The Choroid Coat.
C. The Retina.
D. The Optic Nerve.
E. The Cornea.
F. The Aqueous Humour.
G. The Iris.
H. The Ciliary Processes.
I. The Crystalline Lens.
K. The Vitreous Humour.

* The *sixth*, the *muscular sense* of Bell, has been described at page 229, et seq.

the eye. The membranes or *coats* form the outer part or case of the eyeball, and within them are contained the humours, which have a fluid and semifluid consistence.

The membranes are three in number, and differ from each other widely with respect to their density and other properties.

The humours also vary in their form and consistence.

The preceding drawing presents a *sectional* view of the eye, showing the relative situations of its coats, humours, and nerve.

The eye may therefore be considered as a globular bag, made of three coats, the cavity being divided into three parts, and containing the three humours.

The Sclerotic Coat.

288. This name is derived from the hardness of the membrane, being not dissimilar to tanned leather. It is strong and tough; and being the outside covering, it closely invests the eye on all sides, except the front, where its place is supplied by the cornea. Its want of elasticity renders it very efficient in maintaining the rotundity of the eye, while by its density and strength it assists to preserve the internal delicate structure of this organ from injury, and forms, also, an excellent foundation for the attachment of the muscles of the eye. It is of a white colour, and its texture is such as to be rarely diseased itself, and to form a barrier against external inflammation.

The Cornea.

289. This membrane derives its name from its horny consistence, and is one of the most beautiful parts of the curiously formed organ now under consideration. It occupies all that part of the eye which is transparent, and its edge, where it is joined to the sclerotic coat, may be distinctly seen, the latter being of a dense white, while the cornea itself is as pellucid as crystal. It is more convex than the sclerotic coat, whence the eye bulges out more in front like a watch-glass attached to its outer case. Notwithstanding its superior transparency, it is much harder and firmer than the sclerotic, a quality which will be at once appreciated when its prominent situation is noticed. It is composed of several distinct layers closely united, between which there is constantly exuded a delicate transparent fluid. It is this fluid which, in health, gives to the eye its brilliant and sparkling appearance, and whose diminution and absence in sickness and death causes the well-known dull and leaden inexpressiveness.

The hardness of the cornea, which is so great as sometimes to turn the point of the surgeon's needle, does not interfere with its sensibility. Almost every one has experienced the painfulness of the sensation occasioned by the introduction into the eye of a particle of dust; and the pain of inflammation of this delicate part is more exquisite than that of any other.

Its colourless transparency enables it to trasmit the light without the slightest obstruction to the interior of the eye.

The Retina.

290. This is the innermost of the three coats, and is the immediate seat of vision, or that part upon which the image of the object is impressed.

When the optic nerve has reached the back part of the eye from the brain, it penetrates the two outer coats, and having got within the cavity of the eyeball, it is then expanded over the inner surface of the second coat in the form of an extremely delicate network of nervous filaments; this is the retina. It is of equal extent with the middle coat, and lies in close contact with, but does not adhere to it.

The retina is, in fact, the extremity of the optic nerve, expanded over this large surface that it may receive the image of an object upon whatever part of the membrane it may fall. The colour of the retina, as seen in the dead body, is that of ground glass; during life it is very probably quite transparent.

The Choroid Coat.

291. This membrane lies next within the sclerotic, and between it and the retina, and extends nearly as far towards the front as the sclerotic.

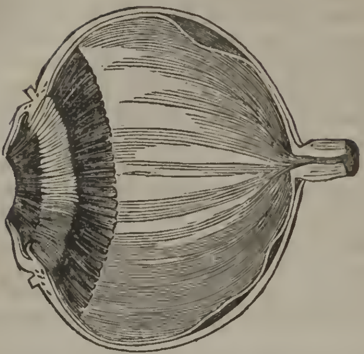
It is composed of two layers, closely united with each other, the outer one of which is copiously supplied with bloodvessels, and the inner one has upon its inner surface a peculiar substance of a black colour, called the *pigmentum nigrum*, or black paint of the eye. This black paint forms a complete covering to all the inner surface of the

choroid, and is in close contact with the retina. Its purpose is believed to be to modify or soften the intensity of the rays of light after they reach the interior of the eye, that the impression of the image upon the retina may have its full force, uninterrupted by the glare. It is with those animals which use their eyes in the light of day that the pigment is seen of the darkest colour; whereas, with those which require their eyes at night, when all the light possible for them to get is necessary for vision, this pigment is either entirely wanting, or it is of a bright reflecting green or silvery whiteness. It is the hue of this pigment which gives to the pupil its particular appearance in each animal.

The pupil of the domestic cat, when seen in a dark room, has a singularly wild and bright yellow glare, which is heightened by the great expansion of the pupil to admit all the light possible. In the human species the pupil has a black colour, corresponding with the black shade of the pigment.

At the front edge of the choroid coat, just within the circle where the cornea and sclerotic are united, the choroid is folded backward and inward in the form of a circular fringe of little threads, which, from their resemblance to eyelashes, are called the *ciliary processes*. These, like the membrane to which they are attached, are covered with the black paint, which, as they embrace the edge of the crystalline lens, serves to absorb some of the rays of light which might otherwise affect the vision.

Fig. 76.



Section of the Eye magnified, showing the Ciliary Processes, the Pigmentum Nigrum, the Retina, and the Choroid Coat.

THE HUMOURS OF THE EYE.

292. Having described briefly the various textures which form the casing of the eyeball, its contents will now be noticed. These are the *Three Humours* and the Iris. The humours are called the *Aqueous*, or *Watery*, the *Crystalline*, and the *Vitreous*, or *Glassy*, and their situations are indicated in fig. 75.

The Aqueous Humour.

293. Immediately behind the cornea, between it and the crystalline lens, is a space which is occupied chiefly by this humour. It is a perfectly clear and colourless fluid, resembling pure spring water. Its chief object appears to be to distend the front part of the eye, and preserve the proper curvature

of the cornea. It doubtless exercises some influence also over the direction of the rays of light as they pass through it. By referring to fig. 75, it will be seen that the space between the cornea and crystalline lens is divided into two compartments, communicating with each other through a circular opening in the centre of the partition. This partition is

*The Iris.**

294. This is a circular membrane, composed of muscular fibres, suspended in front of the crystalline lens, and floating in the aqueous humour. Its object is to regulate the quantity of light passing into the eye, which is admitted through the opening in its centre called the *Pupil.*† This is that part in which we see ourselves in the eye of another. By the enlargement or diminution of this opening, more or less light is admitted into the interior of this organ. The muscular fibres of which the iris is formed, and by whose contractions and relaxations the size of the pupil is regulated, have been described (90, 91).

It is the iris which gives what is called the "colour of the eye," which in some is nearly black, in others blue, gray, hazel, &c. This variety is occasioned by the reflection of the light as it impinges upon the velvety surface of this membrane, and also upon the varied facility with which the black paint which covers its posterior surface is

* So called from its resemblance to a rainbow in its variety of colours.

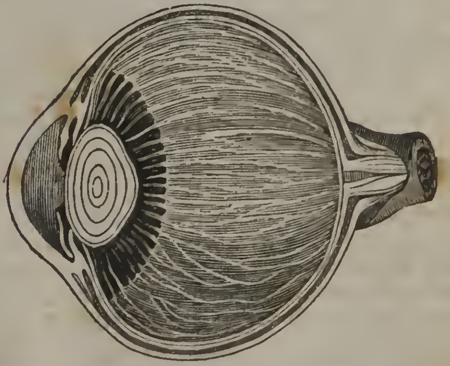
† From *pupa* (Latin), a babe; because it reflects the diminished image of the person who looks upon it. It is commonly called the Apple of the Eye.

seen through it. In a word, it is the greater or less degree of transparency of the iris which chiefly causes its colour.

The Crystalline Lens.

295. This, the second humour of the eye, is situated directly behind the aqueous, and between it and the vitreous humour. Its form is such as to give it the property of a powerful magnifying-glass, convex on its front and posterior sides, but much more so behind than before. It may be said to be somewhat flat in front. In consistency it is not so thin and watery as the aqueous humour, but more nearly resembles "half-dissolved glue," particularly at its outer parts, while its centre is much

Fig. 77.



Section of the Eye magnified, showing the Crystalline Lens in its proper situation, between the Aqueous and Vitreous Humours

firmer. It is much more dense than any of the other humours. In its natural state it is perfectly clear and transparent, and has a very important influence over the direction of the rays of light. When this humour is subjected to the action of alcohol or heat, it becomes hard or *coagulates* throughout, and then it may be separated into distinct laminæ, which are concentric, like the layers of an onion. The lens of a boiled fish, as many of our readers have probably seen, may be served in the same way; in those animals the lens is so very convex as nearly to resemble a sphere in shape.

This humour is closely invested by a firm sac, called its *capsule*, by which it is kept in its place, being attached to and supported by the adjacent parts.

The Vitreous Humour.

296. This fills up all the remaining part, which constitutes the greater proportion of the bulk, of the eye. Its precise situation and extent may be well understood from the preceding figure. It is composed of two parts, of a thin, delicate membrane, formed into numerous irregular cells, which are filled with a thin fluid. The white lines crossing the space in fig. 77 represent the layers of this membrane, which give strength and support to the whole humour. The principal object of this humour is, probably, to keep the retina distended, so as to expose its whole surface to the reception of the light, and to keep the crystalline at the proper distance. It may also, in some degree, modify the light to suit it to the condition of the retina.

297. Having completed the description of those parts of the eye which are immediately concerned in the production of vision, we will now briefly explain the philosophy of its operation, as far as the formation of the image of an object upon the retina is concerned, and then describe the beautiful apparatus by which this delicate organ is protected on all sides from injury.

298. It requires no argument to prove that the imponderable and intangible agent, which we call *light*, is absolutely essential to enable the eye to perceive objects; it is through its action that the various parts of the eye which have been described are enabled to produce an impression upon the optic nerve, by which the figure of objects is conveyed to the brain, and the sense of sight is established. A close and very important relation, therefore, exists between the eye and the light. They were undoubtedly made for each other, and theologians have deemed this among the most convincing proofs of the existence of a great Divinity, which has shaped our frames and made them to correspond with such exactness to external nature. We find that the physical laws which govern the operations of light are precisely adapted to the form and structure of the eye, and that the various parts of this organ are formed individually, and arranged as a whole, in perfect accommodation to the laws of light. No one who has ever examined the structure of the telescope, and has seen how

well it is adapted to its purpose, can hesitate for a moment to believe that it was constructed in accordance with the properties of light, and none other; and that a variation in the relations of the two must render the instrument imperfect or useless. Equally clear is the proof, and as free from the smallest loop on which to hang a doubt, that the eye was designed and constructed with strict relation to the light; to the reception of images through its medium, which was, in due time, to act upon it.

The nature and operation of some of the laws of light, particularly such as have reference to the eye, must therefore be understood before the influences of the humours of the eye can be comprehended.

NATURE OF LIGHT.

299. Light is considered by philosophers to be the peculiar action of a *subtile fluid*, which pervades all space and every substance in nature. Bodies, which appear to us totally dark, contain light in a latent or concealed form. In the darkest night, if a flint and steel are struck together, bright sparks will be emitted, and even the atmosphere then contains as much light in this hidden form as it does in the open day, as may be proved by forcibly compressing a portion of it in a little instrument called the firepump. A bright flash, accompanied with sufficient heat to ignite tinder, will be given out. By this collision of the flint and steel, or compression of the air, the light which was concealed in those substances is merely rendered visible. The

existence of this fluid, therefore, may be independ ent of the sun or any other illuminating power.

The light by which objects are seen is derived either from the sun, or other natural bodies, or from some artificial source. It moves in perfectly straight lines from one point to another, and never in any other, and travels at the rate of twelve millions of miles in one minute of time, occupying about eight minutes in passing from the sun to the earth.

300. Some bodies suffer light to pass through them without obstruction; these are said to be *transparent*, while many other substances arrest its progress, and are hence called *opaque*. When light falls upon an opaque body, it is either absorbed into its substance, or is *reflected* from it in a different direction. Now it is by reflected light that objects are made visible to us; as, for example, when we see a tree, an animal, a rock, or any object, it is by the light which falls upon it from the sun, and is reflected from it to the eye. Such, also, is the manner in which we are enabled to behold the moon; the light of the sun being reflected or thrown back from it to the eye: the varied extent to which the moon is rendered visible to us at different times, depending upon the various positions which it assumes with regard to the sun and earth. In moonlight, likewise, we see objects by the light which is reflected from the moon, that is, after a second reflection from the sun.

301. Light is a compound principle, divisible, according to Sir Isaac Newton, into seven distinct parts or colours, known as the *seven primitive colours*. These are red orange, yellow, green, blue,

indigo, and violet.* These colours, when combined, constitute pure white. The difference in colour which different objects present to the eye, is owing to the reflection of one or more of these rays, and the absorption of the others.

Thus a tree will reflect the green ray, a rose the red ray, a lily the yellow ray, &c., the others being either transmitted or absorbed.

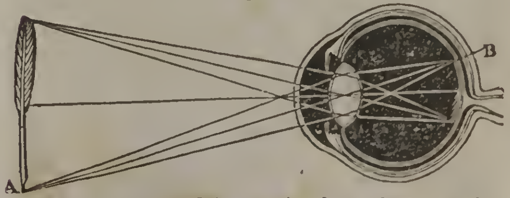
302. One of the properties of light, which is chiefly concerned in the faculty of vision, is called *Refraction.* This signifies the bending of the rays from their original course, and their proceeding in a different direction. This result ensues whenever a ray of light passes from one medium into another of a different density. Thus, when a ray of light, after pursuing a certain direction through the atmosphere, strikes the surface of water, it is immediately bent, and proceeds in a line which forms an angle with the first, and vice versa. This is proved by a simple and easy experiment. If a coin or any small opaque object is placed in the bottom of a white bowl, it can be seen as long as the light reflected from it is not prevented from reaching the eye by the intervention of any opaque body. But when the eye is drawn back so far that the side of the bowl will cut off the view of the object, then, without moving the eye, the latter may be brought into view by partly filling the bowl with water.

* Agreeably to the investigations of some living authors, the phenomena of the prism and of colour may be accounted for on the hypothesis of only three primitive hues, viz., red, yellow, and blue. These, by due admixture, are supposed to form all others.

The eye, in the position described, cannot see the object in the bowl by the direct ray. But when the water is in the bowl, some of the rays which pass up to the surface are *refracted*, the moment they reach the air, towards the eye, which is thus enabled to see the object.

303. Upon this property of refraction, the humours of the eye, more especially the crystalline lens, depend for their power of producing the image upon the retina. The lens is so situated behind the pupil, that it receives all the light that enters the eye through that opening. The moment the light reaches the surface of the lens, it takes a different direction, and again a different when it reaches the opposite surface of the lens. The conjoined effect of these variations in the direction of the rays is to converge them at a certain point within the eye, and that point upon the retina where an impression is made, which, being transmitted to the brain, gives rise to the sense of vision. Fig. 78 shows the directions in which the rays are refracted, and the manner in which they unite within the eye to form the image.

Fig. 78.



304. An *inverted* image is thus shown to be produced upon the retina, a fact which, to the

young and uninformed mind, is a subject of great difficulty. The law of "visible direction," as it is called, explains this subject. "It will be observed that the rays of visible direction cross each other at the point or centre of visible direction; those from the lower part of the picture go to the upper part of the object, and those from the upper part of the picture go to the lower part of the object; and thus, when the mind would perceive the top of an object, it refers from the bottom of the picture *upward;* and when it would perceive the bottom of an object, it refers from the top *downward*, whereby a true notion of the erectness of objects is obtained (as, indeed, it only can be) by means of an inverted picture."

The means by which the eye is enabled to accommodate itself with such wonderful facility and completeness to every required position, viz., its numerous muscles, will be understood by referring to fig. 32 and paragraph 93.

THE PROTECTIONS OF THE EYE.

305. This part of our subject presents, perhaps, more elegant and pleasing proofs that a wise and benevolent intelligence has planned and superintended the construction of our frames, than any other portion of the machine. Indeed, the eye, both in its internal and external arrangement, abounds in such exquisite contrivances, that, independent of the fact that it is *alive*, it seems strange that any mind can hesitate for a moment to acknowledge the gift as from an inscrutably wise Creator, and to feel that all the devotion he is capable of rendering to the author of his being can

be but a meager return for the enjoyment and security derivable from the gift.

So delicate an organ as the eye, particularly when placed in a situation necessarily so exposed, would seem to require all the conservative means possible; and yet these must be of such a character as not to interfere in the least with the function of the organ. To steer between these two points would, à priori, seem impracticable; and we are astonished at the apparent facility and the complete efficiency with which the object has been attained; and we are forced to the conclusion that none but an Omniscient being could have accomplished it.

The Orbit.

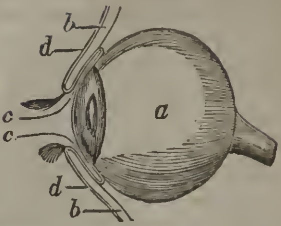
306. The ball of the eye, it is first to be observed, is placed very securely in a strong bony cavity, called its *orbit* or socket. This is formed of several individual bones, which chiefly belong to the scull, but some of them to the face. They are so united together as to form a deep chamber, apparently excavated in the cavity of the head; but it is, in fact, formed by projections of the forehead bone and the cheek bone running backward, and completing the side, bottom, and top, leaving the necessary holes for the passage of the nerves and bloodvessels. In shape, each orbit is like a funnel, with the larger end in front. The inner surface of the cavity is very even and smooth, that it may present no impediment to the free and uninterrupted movements of the ball. But these motions are so numerous and incessant, that the

smoothest possible surface of hard bone would have a great tendency to irritate and inflame the tender globe; added to which, there would be danger of derangement and injury of its delicate humours and membranes, arising from the numerous concussions of the body. To avoid these, we find the whole orbit lined within with a soft cushion of elastic fat, of considerable thickness, upon and in which the eye securely reposes, and which affords much assistance to its numerous muscles. The reader, by examining the edges of the socket of his own eye, will observe a considerable projection of the bones above, below, and at the sides. The brow, in fact, overhangs the eye considerably, while the nose extends between the two orbits, so that in a fall upon the face the eye is the most likely of all parts to escape injury.

The Curtains of the Eye.

307. The next point which it would seem necessary to guard against, is the intrusion of particles of dust and other matters floating in the atmosphere. This is effected by a fine membrane, so arranged as to form a complete covering to the front of the eye, as well as to the other adjacent parts. This membrane is an extension of the skin which covers the eyelids outside, and which, as it turns inward to the inside of the lids, becomes changed in character so as to be accurately adapted to the front of the eyeball, without in the least interfering with vision.

Fig. 79.



Let *a* represent the eyeball, and *b b* the upper and lower lids, with the lashes attached. The passage *c c* is that through which dust, &c., enter, and which would come in immediate contact with the cornea, if not prevented by the contrivance now under review. The common skin of the eyelids *d d*, after turning over their edges, goes inward and lines the *inside* of the lids; having done which, it is doubled upon itself, and passes directly over the cornea, lying against it and protecting it. But at this part a remarkable change occurs in its structure. Outside of the eyelids it is similar to the skin which covers the whole body, opaque and comparatively dense; but, when it arrives in front of the eye to cover it, it becomes *perfectly transparent.* This same skin, therefore, partakes of these two entirely distinct properties at different parts, being adapted, with marvellous economy, to its different requisitions. It is called the *tunica conjunctiva.*

The Eyelids.

308. In these also we have additional proof of

the skill and beneficence of the contriver. The iris has been stated to be the principal regulator of the quantity of light proper to be admitted into the eye for the purpose of vision. But there are many situations when this delicate muscle would be inadequate to protect the eye from too severe a glare of light, which, if not guarded against, would be very painful to the eye, and often injurious to its power of seeing. There are times, also, when it becomes desirable to exclude *all* light from the eye, as during the hours of sleep, which the presence of light would disturb, if freely admitted. Instead of being obliged to draw close the curtains of the bed, or to cover the eyes with a bandage, we are supplied by nature with curtains, than which nothing could more effectually answer the end desired. The dense eyelids are therefore given us for the double purpose of protecting our eyes from too great a brilliancy of light, and also against the encroachments of denser substances, against which the *conjunctiva* would prove an insufficient guard.

309. The eyelids are formed of common integuments, and are therefore very soft and flexible. Along the edge of each is a little strip of cartilage, which gives them shape, and being formed somewhat like a hoop, it serves to stiffen them, and yet is so flexible as to enable them, when closed, to fit against each other with the most perfect accuracy. Both lids are supplied with appropriate little muscles, which produce all their movements. The upper eyelid is the only one moved for the admission of light; it is raised by a muscle just beneath its skin, called the *elevator*. The muscle which closes the eye has been described (90).

The margin of each eyelid is lined just beneath the skin with a row of very small glands, called *Meibomean* Glands*, whose purpose is to secrete an unctuous fluid, which is poured through twenty or thirty little tubes or ducts upon the edge of the lid. The object of this is to protect the part from being irritated by the tears, and also to assist the lids to form a complete closure. During the night this fluid collects in the corner of the eye in a dry state, and is that which we rub away in the morning.

310. Still farther do we find the eye furnished with protections. The lids are fringed with a border of stiff projecting hairs, the eyelashes. These, standing out prominently in front of the eye, make a very important addition to the means of warding off particles of dirt, and serve as barriers against the approach of insects. They also serve the important purpose of mitigating the too fierce impression of the sun's light, besides adding very greatly to the beauty and expressiveness of the eye.

The Tears.

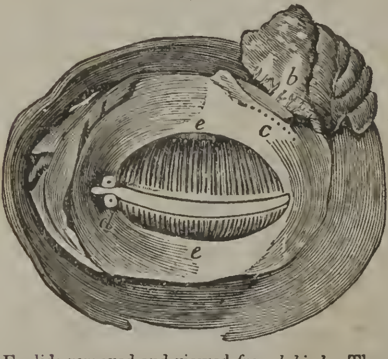
311. There is now to be described the apparatus by which the eye is kept continually in a fresh and moistened state, that it may the better perform its important office. Every one can understand how necessary it is that the front part of the eye should be kept bright and clean, that all impurities and foreign bodies should be immediately removed. For these purposes we find a continual stream of water pursuing its crystal course over the eyeball. The apparatus which supplies this fluid consists of

* From the name of their discoverer.

several parts, viz., a gland called the *Lachrymal*,* with appropriate ducts; a sac to collect the fluid after it has passed over the eye; and a tube to convey it away into the nose. These little "water-works" may be better understood by reference to the following cuts.

The *Lachrymal Gland* is situated at the upper and outer corner of the eye, in a depression of the edge of the orbit. It secretes the fluid of the tears from the blood, and discharges it by its little ducts directly upon the surface of the eye. The ducts open upon the inner surface of the upper eyelid.

Fig. 80.



The Eyelids removed and viewed from *behind*. The Lachrymal Gland is seen at the right hand upper corner. *b*, the Ducts issuing from it. *c*, the Mouths of these ducts. *d*, two small Holes forming the mouths of a double canal for draining off the tears from the eye into the nose. *e*, the Meibomean Glands.

312. As the fluid which is poured out from the

* From the Latin for *tear*.

ducts of the gland runs over the front of the eye, the eyelids assist it in sweeping away the moats and other impurities which are lodged upon it, by the process of "winking." If a particle gets upon the eye which is too large to be washed off by the ordinary flow, the pain which it produces operates as a stimulus upon the lachrymal gland, and causes it to pour out a more abundant secretion, to remove the offending object.

313. When the fluid arrives at the inner corner of the eye, after having passed over its surface, it is not suffered to accumulate there or to run over the lids, which, in the first place, would partially interrupt the sight, and, secondly, would produce great irritation of the lids, and, perhaps, disease of the Meibomean glands and decay of the eyelashes. To convey away the fluid as rapidly as it is formed under ordinary circumstances, there is provided a neat little apparatus at the inner corner of the eye. A little sac, called the *Lachrymal* Sac, capable of containing several drops, is placed in a depression of the bone in such a manner that its mouths (*d*, fig. 80) will receive all the fluid which flows against them, taking it up by capillary absorption. At the opposite side, the sac opens into a tube, called the duct, which descends perpendicularly through a canal cut in the bones *purposely for it*, and opens in the cavity of the nose (fig. 81). As the fluid descends drop by drop into the nasal cavity, the warm air, as it rushes through, dissipates it in vapour.

It sometimes occurs, however, that the flow is entirely too copious to be carried away by the sac and duct, an event producible by various causes,

Fig. 81.

The Eyelids viewed from before. *a*, the Ducts which absorb the fluid. *b*, the Sac and Duct which convey it to the nose. At the opposite corner is the Lachrymal Gland.

such as emotions of the mind, bodily suffering, &c. The outpourings of the lachrymal gland then filling the space between the eyeball and the lids, it overflows the boundaries and courses down the cheek as the eloquent tear.

314. We have stated that this effusion of the lachrymal gland is continually exuding and washing over the front of the eye, and is aided in its operation by the process of winking. During sleep, however, the eyelids are closed and the latter action does not take place, whereby a partial stagnation of the fluid would be likely to occur, and its collection to cause inflamed eyes. A beautiful provision against this occurrence is found.

We have already described the means by which the lids are kept in their curved form, viz., a little strip of cartilage lining the edges. Now, when the lids are closed, these little strips are so formed as to incline inward in such a manner as to touch only at their outer edges, and leave behind a triangular gutter (fig. 82 presents the profile view), along which the water runs without interruption, discharging itself freely at the opposite end.

Fig. 82.

The Eyebrows.

315. There remains to be noticed but one other defence against the encroachments of foreign substances. It has been decreed that man should earn his bread by the sweat of his brow, and it is well known that this part of his body perspires more copiously during labour and sultry weather than any other; the "briny drops" often run down in profuse quantities. The eye being directly in the range of the descending fluid, it became necessary to protect it in some way against the injury it would produce if allowed to come in contact with the delicate organ. We are therefore provided with a row of strong, closely-set, and glossy hairs, placed upon the prominence of the brow, which, being all inclined in one direction, outward, serve rather to retain the drops until they may be evaporated or wiped away, or to conduct them off towards the temple. Thus is the eye preserved from the descending currents as effectually as a house by its tiled roof.

THE EAR.

316. In point of importance to our welfare and happiness, the faculty of hearing is scarcely inferior to that of sight. If we should undertake an enumeration of instances in which we would suppose the one to be of more importance than the other, we should probably give the predominance to the sight, and yet, in the aggregate, there would be but a trifling difference between them. One could hardly decide which he would prefer to retain if he were obliged to give up one or the other.

"Le Cat, in his *Physical Essay on the Senses*, very justly observes, that 'life deprived of sensations so useful as hearing is a kind of premature death.' A deaf man is necessarily a dumb man, and who can compute his loss? His never-sleeping guard is dead, who warned him of a thousand dangers; and now the tread of the midnight thief, the crash of the falling tree, the screaming of the drowning child, or the mutterings of the coming storm, fall upon his ear as vainly as the tear of sorrow upon the brow of death. Who can compute his loss? The rejoicing melody of spring, the sweet echoes of the valley, the loud artillery of heaven, the voice of friendship, and the hallelujahs of the Sabbath, are alike condensed into barren nothingness, and in the very excess of stillness he even parts with the sense of silence."

The organ which affords us such important protections and such exquisite delights is of a structure commensurate in beauty and ingenuity with such noblo and agreeable attributes.

OF SOUND.

317. The sensation which we denominate sound is usually produced by undulations of the atmosphere, which, striking upon the apparatus of the ear, give rise to the peculiar sense. These undulations are caused by vibrations of the body which is heard. Thus when a bell is struck, its vibrations may be distinctly seen, and sound is given forth as long as these vibrations continue. Each vibration produces a separate undulation of the air against which it strikes, and, consequently, a separate sound; but one continuous noise is perceived by the ear, in consequence of the vibrations succeeding each other so rapidly that the mind is unable to appreciate the difference between them.

The vibrations of the string of a harp, piano, or violin, produce the same effect, the difference in the sounds of different strings being occasioned by their difference in size, length, and tension, and, consequently, the magnitude of their vibrations. That sound is the result of these vibrations is very easily proved by arresting the vibrations, by laying the hand upon the string or bell, when we arrest the sound at the same time.

318. The atmosphere, however, is not the only means by which sound can be conveyed. Any material in which vibrations can be produced will answer to a certain extent. Thus liquids may bo thrown into undulations and will convey sounds, and, in fact, with an increased effect over air. This is readily proved by putting the head beneath the water and striking two stones together; a

shock is produced which is very loud and disagreeable. Solid substances likewise will convey sounds more audibly than can the air, though the distance is limited by the extent of the body. Thus, if a person applies the ear to one end of a long beam of wood, the noise produced by the scratching of a pin upon the opposite end may be distinctly heard, while the air will not convey it more than a few inches. The wood conducts the sound by its own vibrations, but they are not sufficiently strong to impart undulations to the air. It is said of the North American Indians, that they are able to hear the sound of footsteps at an incredible distance by applying the ear to the ground. The earth will transmit a sound which the air cannot.

319. Sound, like light, is capable of being reflected from smooth surfaces. The whispering gallery (a smooth circular wall) proves this; the noise of a slight whisper, by reflection from one part to another, may be transmitted so as to be audible at a distance of several hundred feet. Echo is reflected sound; the reverberation of the human voice is sometimes so complete from the side of a mountain or high wall, as to be as distinct as the voice itself, though the reflecting object be a quarter of a mile off.

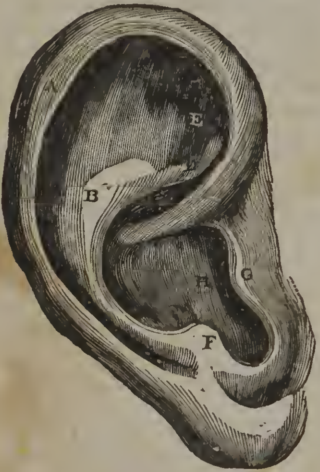
The three general principles which we have mentioned as connected with the phenomena of sound, are all provided for in the construction of the auditory apparatus of animals. The undulations of the air are received by the external ear, which is so arranged as to prevent the escape of the sound, by reflecting it from point to point till it

reaches the inner opening, and then the internal organization is such as to exemplify the conductibility of solid substances.

THE EXTERNAL EAR.

320. This part of the auditory apparatus is mostly formed of elastic cartilage, covered with a delicate skin. Its general form is cupped, but it

Fig. 83.



The External Ear.

A, the *Helix*, or raised border of the ear. B C D, the *Antihelix*, a triangular elevation of the cartilage. E, the *Scapha* (from its resemblance to a skiff), a depression. F, the *Tragus* (signifying a goat, because it is armed with little hairs, like a goat's beard), a cartilaginous projection. G the *Anti-tragus*

(being opposite to the latter). H, the *Concha*, or great cavity of the ear, leading into the inner opening. The most dependant part of the ear is the *Lobe*. This is a small mass of fat, and is that part which is pierced for the ear ring. It serves to prevent the sound passing down in the direction of the jaw, besides forming an ornamental appendage.

is divided into a number of ridges and depressions, which are admirably arranged to catch, and retain, and convey inward whatever may fall upon it. Many inferior animals have, in an exalted degree, the power of moving the ear in all directions, by which it is assisted in catching sounds from whatever quarter. Uncivilized man possesses this property, but in a very limited degree. To accomplish it, the ear is provided with a few small muscles. The various elevations and depressions of the external ear have had names given them, which are described in fig. 83.

At the bottom of the concha is the commencement of

The Tube of the External Ear.

321. This is a passage leading to the interior of the organ, and is marked in the temporal bone of the scull, fig. 59. The tube itself is formed chiefly in the body of this bone. It takes a direction a little upward and forward, and then makes a slight turn to descend. As this tube is always open, and destitute of any such protection as the eye has in its lids, it is, of course, constantly obnoxious to the entrance of insects and other injurious bodies. Were it furnished with any means which could completely shut it off from the external air, an impediment to the entrance of sound would also be the result, a circumstance which

would deprive us of our principal means of protection during sleep and other times when it should be found desirable to close the eyes. Still it is necessary that the ear should be guarded against the encroachments of injurious substances, and that without any hinderance to this important sense. We find, accordingly, a provision for this end. The lining of the tube is studded with fine hairs, projecting towards the centre, which are mostly long enough to interlace with those from the opposite sides, and thus form a barrier to the entrance of anything but sound, and bodies which are sufficiently hard and heavy to force their way in. Among the roots of these hairs are imbedded numerous small glands, which secrete a wax of exceedingly bitter taste, which covers the surface of the tube, and which serves either to deter insects from entering, or to entangle them after their entrance, and prevent their farther advancement.

The Tympanum.

322. At the inner end the tube is closed by a membrane stretched across the passage, which is known to all as the *drum of the ear*, technically the *tympanum.* It is somewhat of an oval form, and is slightly depressed in the centre. It is very thin and delicate, and is so situated as to receive all the vibrations of the air which enter the tube, and convey them to the inner part of the ear. Immediately behind this membrane is a small irregular space, called the *cavity of the tympanum*, and at the opposite side of this are the openings to the more interior parts. The drum completely separates the internal from the external cavity. Now

the drum can only communicate the vibrations of the air to the inner apparatus by vibrating itself; but this it could not do unless the cavity behind it also communicated with the external air. This it does through a tube which opens into the back part of the mouth, called the *Eustachian* tube from the name of its discoverer.

BONES OF THE EAR.

323. In the cavity of the tympanum are situated four bones, which are the smallest, the most delicate, and beautifully shaped bones in the body. They are named after bodies which they resemble in shape, as the mallet, the anvil, the orbicular, and the stirrup.

Fig. 84.

Malleus. Incus and Orbiculare. Stapes.

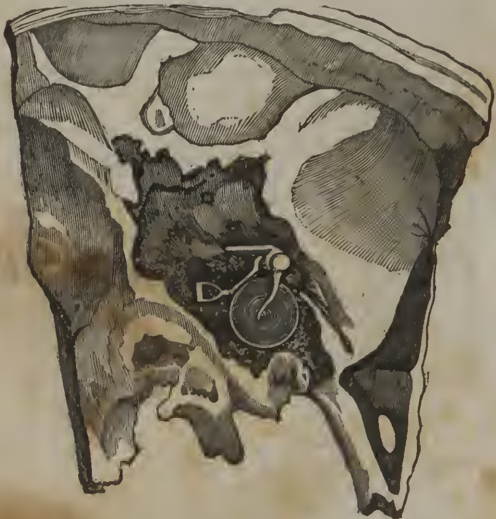
Bones of the Ear.

The first resembles a rudely-formed hammer, and the incus a blacksmith's anvil. The orbicular bone is the smallest in the body, not being larger than the head of a pin, and the stapes exactly resembles a stirrup iron in form. These little bones form a chain extending across the cavity of the tympanum, one end of which is attached to the inside surface of the drum, being applied to its centre where it projects inward; and the other end

communicating with an exceedingly intricate apparatus within the temporal bone, where the nerve of hearing is distributed.

The following cut presents a view of the *inside* of the temporal bone, showing the cavity of the tympanum, and the drum and bones of the ear in their natural positions.

Fig. 85.



At the inner end of this chain of bones there is placed the remainder of the auditory apparatus, which is the most intricate and complicated structure of the whole frame, though very small in extent. It is contained in a portion of the temporal

bone, which, from its extreme hardness, is called the *Petrous*, or rocky portion (235). Within a small cavity in this hard bone is contained the *Labyrinth*, which is divided into three several parts, called the *vestibule*, the *semicircular canals*, and the *cochlea*. These various parts of the labyrinth contain a delicate aqueous fluid, through which is distributed the auditory nerve, which receives all the tremours of the little bony chain, which receive them from

Fig. 86.

General sectional view of the Structure of the Ear magnified. *a*, the External Opening; *b*, the Drum or Tympanum; *c*, the Malleus; *d*, the Incus; *e*, the Orbicular bone; *f*, the Stapes; *g*, the Semicircular Canals; *h*, the Cochlea; *i*, the Inner Opening, through which the auditory nerve enters the ear from the brain.

the drum, and carry them onward on the principle before stated (318).

Fig. 86 presents a very clear view of the general arrangement of the various parts of the ear, and with this we will close this part of our study.

THE NOSE.

324. The sense of perceiving odours is one which contributes much to enhance the pleasures and comforts of life, and to guard it from injury. In point of importance, it is inferior to all the others, but it is a powerful adjuvant to them in many circumstances. It is one which rarely becomes permanently impaired or lost; but when it is entirely obliterated, the other senses supply the deficiency very nearly. The use of this sense is principally to assist in protecting us against the danger of admitting noxious materials into the mouth. For this end, its situation is the best that could possibly have been devised; placed directly over the entrance to the stomach, everything that goes into the mouth must pass under its immediate inspection. It is in this light that this sense is particularly useful to inferior animals; for most of them depend wholly upon it as their guide to proper food, and protector from that which is injurious. In them, therefore, it is a far more important faculty, and in proportion to its necessity is it made acute; it is the compensator for the want of acuteness of other senses, especially that of sight. The hound, it is well known, can trace the game over the ground for miles, guided only by the odour which the latter leaves in its flight, though scarcely touching the soil over which it flies.

The organ of this sense is placed also directly at the entrance to another important function, which it is equally necessary to guard against noxious agents. Allusion is here made to the respiration, the food for which passes mostly through the nose. Can it be doubted that *design* is exhibited in the location of this faculty, guarding as it does, so completely, the two great avenues to life, health, and comfort? Under its protecting care, impure air and injurious food are detected and avoided, and the most important functions of animal life are carried on with confidence, unmingled with fear or suspicion.

325. Smell is the perception of the effluvia of bodies by the mind. To constitute the faculty, there are, therefore, three things necessary: 1st, A nerve to receive an impression; 2d, An organ for the proper arrangement and distribution of the nerve; and, 3d, Particles of matter to produce an impression upon the nerve.

The nerve which is devoted to this sense is denominated the *Olfactory* Nerve.* It proceeds from the brain a single thread, one on each side, and runs directly to the nose. It is very peculiar in the mode in which it makes its exit from the inside of the scull. All other nerves pass out through a single opening, and, without dividing, go on to their destination; but this nerve, immediately before it gets out from the cranial cavity, is separated into a number of small filaments, each of which goes through a separate opening, all being near to each other. That part of the scull, there-

* From *Olfactus* (Latin), the smell.

fore, has somewhat the appearance of a sieve, and from that its technical name (*Cribiform Plate*) is derived. This plate of bone is immediately over the top of the nose, between the orbits of the eyes. Having descended through these openings, the nerve is spread immediately over a membrane which lines the inside of the nostrils, and which is peculiarly adapted to it, and in this simple manner the olfactory apparatus is constituted.

The lining membrane of the nose is, however, more extensive than is perhaps generally supposed. The bones of which this part is constructed are extremely irregular and winding; projections of bone are thrown inward from the sides of the cavity, which curl upon themselves so as to present as great a surface as possible to be covered by this membrane, but without interfering in the least with the passage of the air through the nostrils.

326. The organ of smell being thus constituted, the particles of matter whose odour is perceived are carried by the air which is drawn in through the nose, and brought into immediate contact with this membrane and the nerve by which it is freely supplied, and by which the peculiar impression made upon it is conducted to the brain. To facilitate the operation, the membrane is supplied with a great number of minute glands, which exude a glairy adhesive fluid called *mucus*. Against this the fine particles of odorous matter adhere, and, being retained, opportunity is given for a more distinct impression to be made upon the nerve.

THE TONGUE

As the Organ of Taste.

327. The only remaining sense to be described is that of TASTE, which is one that, in respect to its important bearing upon our health and comfort, is scarcely inferior to any. It is upon this that man principally depends as his chief aid in discerning proper nourishment. It is placed immediately in the avenue to the stomach, and everything that enters that cavity must come in immediate contact with the organ of this sense, whereby its quality must be immediately detected before it has been swallowed. It is true that we are oftentimes deceived by this sense respecting the propriety of certain articles, as many baneful substances have an agreeable taste. This merely shows that our reason and judgment, which have been wisely and graciously bestowed upon us, are to be employed as correctors of our senses, and that the latter are not to be trusted alone; if uncorrected, they would often lead us into dangers. The brute creation, which depend more entirely upon their animal senses, have this as well as the other senses correspondingly exalted in degree.

328. The organ of taste consists of a nerve called the *Gustatory*,* and a peculiar arrangement of membrane, spread over the tongue, and the sides and back of the mouth. The principal bulk of the tongue consists of muscular fibres, interspersed with a little fat, whence it derives its surprising

* From the Latin for taste.

flexibility; it is covered by a continuation of the common integuments, reduced very thin and made very delicate; through this the extremities of the gustatory nerve are dispersed. Upon the surface of this membrane may be seen with the magnifying glass, and sometimes without it, numerous little elevated points, called *Papillæ*. There are two sets of these, differing in their offices and size. Those at the root and middle of the tongue are the larger, and are little glands which secrete a portion of the saliva with which the mouth and tongue are continually moistened in health. Those at the *tip* and *sides* of the tongue are smaller and more numerous, and of a brighter red colour; it is these latter which possess the faculty of perceiving the flavour of substances which come in contact with them. Each of these papillæ contains several fine *nervous filaments* and numerous bloodvessels.

329. The substance which is tasted comes first in contact with the papillæ on the tip of the tongue, and if it is of a moist or juicy nature, its peculiar flavour is at once perceived; but if it is dry and solid, it is necessary that it should be partially dissolved, and for this purpose it is carried farther back, where it mixes with the saliva, and imparts to it its flavour, and thus becomes appreciable to the extremities of the nerve. Some substances are so entirely insoluble that they cannot be tasted at all, though held in the mouth for a long time. The surface of the tongue must be continually kept in this moist state to render the faculty of taste available. When the mouth becomes parched and dry, as during the existence of a fever, this useful and pleasurable sense is almost wholly lost, even

to the most sapient and highly-flavoured bodies. Several of these tasting papillæ are scattered over the sides and back part of the mouth. On this account, some persons who have unfortunately lost their tongues are not deprived of the sense of taste.

For a description of the sense of Touch, the reader is referred to page 192, et sequitur.

THE END.